United States Court of Appeals

for the

District of Columbia Circuit

TRANSCRIPT OF RECORD

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United States Court of Appeals for the District of Columbia

OCTOBER TERM, 1935

793

No. 6576

HAZELTINE CORPORATION, AND HAROLD A. WHEELER, APPELLANTS,

vs.

CONWAY P. COE, COMMISSIONER OF PATENTS.

APPEAL FROM THE SUPREME COURT OF THE DISTRICT OF COLUMBIA.

FILED OCTOBER 22, 1935.

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United States Court of Appeals for the District of Columbia

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INDEX.

	Original	Print
Caption	*a*	1
Bill	1	2
Answer to the bill of complaint	8	8
Findings of fact	10	10
Conclusions of law	11	10
Final decree	12	11
Petition for appeal	12	11
Order allowing appeal and fixing bond	13	12
Citation	13	12
Memorandum: $50 deposit in lieu of bond on appeal	14	13
Assignment of errors	14	13
Order making statement of evidence part of record	16	14
Designation of record	17	15
Clerk's certificate	19	16
Statement of evidence	20	17
Testimony of Harold A. Wheeler	21	17
Ralph H. Langley	68	52

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—7129-C

	Original	Print
Affidavit of Louis Alan Hazeltine	95	
Milton Mervin Eells	99	76
Vernon E. Whitman	102	78
Plaintiffs' Exhibit No. 1	109	83
No. 2	110	84
No. 3	233	89
No. 4	300	92
6A	336	117
6B	341	122
6C	344	125
8	349	130
Defendant's Exhibit A	353	133
B	360	140
F	368	147
G	372	150
H	379	155
I	385	160
J	394	168
Stipulation as to printing exhibit	400	175

United States Court of Appeals for the District of Columbia

No. 6576.

Hazeltine Corporation, and Harold A. Wheeler,
Appellants,

vs.

Conway P. Coe, Commissioner of Patents.

---

a Supreme Court of the District of Columbia.

In Equity.

No. 55874.

Hazeltine Corporation, and Harold A. Wheeler,
Plaintiffs,

vs.

Conway P. Coe, Commissioner of Patents, Defendant.

United States of America,
District of Columbia, ss:

Be it remembered, That in the Supreme Court of the District of Columbia, at the City of Washington, in said District, at the times hereinafter mentioned, the following papers were filed and proceedings had, in the above-entitled cause, to wit:

1 In the Supreme Court of the District of Columbia.

Equity.

No. 55874.

Action under Sec. 4915, Revised Statutes.

HAZELTINE CORPORATION, and HAROLD A. WHEELER,
Plaintiffs,

v.

CONWAY P. COE, Commissioner of Patents, Defendant.

Bill.

Filed July 1, 1933.

To the Honorable Judges of the Supreme Court of the District of Columbia:

Plaintiffs, for their Bill of Complaint, allege that:

1. The Plaintiff, Hazeltine Corporation, is a corporation organized and existing under and by virtue of the laws of the State of Delaware, is a citizen of said State and has its office and principal place of business at 15 Exchange Place, Jersey City, N. J. The Plaintiff, Harold A. Wheeler, is a citizen of the State of New York and a resident of Great Neck, Long Island, County of Nassau, State of New York, formerly of the City of Baltimore, State of Maryland. The Defendant Conway P. Coe, is a resident of Chevy Chase, County of Montgomery, and State of Maryland, and is a citizen of that State, and in his official capacity as Commissioner of Patents, is domiciled in the District of Columbia.

2. The jurisdiction of this Court depends upon the patent laws of the United States, this being a suit in Equity under Section 4915, Rev. Stat. (Comp. Stats. 9460; U. S. C., Title 35, Sec. 63) as amended by the Act of March 2, 1927, to secure an adjudication that Plaintiff, Hazeltine Corporation, is entitled to receive a patent for the invention as specified in the rejected claims hereinafter referred
2 to, or for any part thereof, as the facts of the case
may appear, and that the Defendant be authorized to issue such patent.

3. Heretofore, and prior to the 7th of July, 1927, Harold A. Wheeler was the true, original and first inventor of certain new and useful improvements in "Amplifier Volume Control", not known or used in this country, and not patented or described in any printed publication in this or any foreign country, and not in public use or on sale in this country prior to the invention and discovery thereof by the said Harold A. Wheeler, or for more than two years prior to the hereinafter recited application for Letters Patent therefor, and for which invention no application for Letters Patent had been filed in any foreign country by the said Harold A. Wheeler, or his legal representatives or assigns more than twelve months prior to the said hereinafter recited application for Letters Patent, and which invention has not been abandoned.

4. Being, as aforesaid, the first, original and sole inventor of the said invention, and being entitled to a patent therefor, the said Harold A. Wheeler did, on or about July 7th, 1927, file in the United States Patent Office, an application for Letters Patent on said invention, the said application complying in all respects with all the requirements of the law in such cases made and provided; said application having been duly identified by Serial No. 203,879.

5. On or about July 6, 1927, Plaintiff, Harold A. Wheeler, executed and delivered an assignment to the Plaintiff, Hazeltine Corporation, of all right, title and interest in and to the said application, the invention thereof and all Letters Patent to be issued upon or for the same, authorizing and requesting the Commissioner of Patents to issue to Plaintiff, Hazeltine Corporation, any and all United 3 States patents which might be granted upon or for said invention, such assignment having been duly recorded in the Patent Office of the United States, on or about the 7th day of July, 1927, in Liber E 131, page 227, Transfers of Patents; and a duly certified copy of said assignment will be produced in Court as your Honors may direct.

6. The said United States application for Letters Patent was duly prosecuted in the United States Patent Office, the following claims (among others) having been submitted to the Primary Examiner:

68. In a radio receiving system responsive to signals which may have any intensity within a wide range, a signal translating system including a vacuum tube having an anode circuit, a detector which produces a rectified component of said signal, means causing said rectified component to vary the anode current of said tube in correspondence with the received signal intensity, and means responsive to said anode current for visually indicating variations of received signal intensity.

69. In a radio receiving system responsive to signals having a large range of input intensities, an automatic control electrically linking portions of said system for maintaining the signal output intensities of said system within a small range, and means of small range for visually indicating said output intensities and thereby automatically indicating said input intensities.

72. In a signaling system including a multistage vacuum tube amplifier tunable to resonance with a signal frequency, the combination of means for automatically maintaining the amplified signal intensity substantially constant whereby audible indication of resonance is im-
4 practicable, and means for visual indication of
resonance comprising a current-indicating device which responds to variation in the plate current of one or more of said amplifier tubes.

73. A receiving system for high-frequency currents comprising tuning means for causing the system to respond to current of desired frequency, means for producing an audible response to modulations in the received current which is of constant volume over a range of variation of intensity of high-frequency current at said desired frequency, and visual means for indicating when the tuning means is in proper adjustment for control of said audible response by said second means over the maximum range of said variation in intensity.

74. In a high-frequency receiving system, an electron discharge device having an anode circuit, a cathode and a grid, a tuned circuit connected between the cathode and grid whereby the receiving system may be adjusted to respond to current of desired frequency, sound reproducing means, means for supplying current from the device to said sound reproducing means, means for controlling the static potential on the grid in response to the intensity of

the received current thereby to produce a substantially constant volume of sound from the sound reproducing means over a range of intensities of received current, and means responsive to the magnitude of current flowing in the anode circuit for visually indicating the condition of adjustment of the tuned circuit with reference to the frequency of received current, whereby said tuned circuit may
be adjusted in accordance with said last-named
5 means independently of the audible indication sup-
plied by the sound reproducing means.

75. In a signaling system including a vacuum tube amplifier tunable to resonance with the frequency of the received signals, the combination of means for adjustably tuning said system to resonance with a signal frequency, means for automatically maintaining the amplified signal intensity substantially constant by control of the plate current of said amplifier, whereby the usual audible indication of resonance is impracticable, and a milliameter connected in the plate circuit of one or more of the automatically controlled vacuum tubes of said amplifier, resonance being visually indicated by minimum current through said meter.

76. In a modulated-carrier-current signaling system including a vacuum tube amplifier adjustably tunable to resonance with the carrier-current frequency and a rectifier coupled to the output of said amplifier for detecting the modulations, the combination of means for automatically maintaining the modulation signal intensity substantially constant during fluctuation of the received carrier-current by automatic control of the plate current of said amplifier, and indicating means directly actuated by change in plate current of said vacuum tube amplifier for indicating a condition of resonance of the vacuum tube amplifier with the carrier-current frequency.

77. In a modulated-carrier-current signaling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct current connection from said rectifier to an element of said amplifier for applying to a control electrode of said
amplifier a biasing voltage derived from the output
6 circuit of said rectifier, whereby amplification is reg-
ulated automatically, and a connection from said
rectifier to a modulation current amplifier whereby the signal is further amplified, said carrier-current amplifier

being tunable to resonance with the carrier-current frequency, and means responsive to the carrier-current for visual indication of resonance.

The said claims were finally rejected erroneously, as Plaintiffs believe, by the Primary Examiner May 6th, 1932 and July 14th, 1932; upon the following alleged prior art:

U. S. patent to Perry, No. 1,536,130, issued May 5, 1925;

U. S. patent to Friis, No. 1,675,848, issued July 3, 1928;

Proceedings of Institute of Radio Engineers, 1923, pages 115-152.

An appeal was thereupon duly taken by Plaintiffs to the Board of Appeals, who, by decision rendered February 1, 1933, affirmed the decisions of the Primary Examiner, also erroneously as Plaintiffs believe.

6(a) A duly certified copy of the file wrapper and contents as including said application, showing the Patent Office proceedings and the said decision of the Board of Appeals, and duly certified copies of the cited alleged prior art patents and publication, will be produced as your Honors may direct.

7. Under the provisions of the said Act of March 2, 1927, the said decision of the Board of Appeals, dated Feb. 1, 1933, constitutes a refusal by the Commissioner of Patents to grant a patent on said invention as defined by said claims Nos. 68, 69, 72 to 77, inclusive; and no appeal has been taken from the decision of the Board of Appeals to the Court of Customs and Patent Appeals, and no such appeal is pending or has been decided. Said decision of the Board of Appeals was delivered on or about Feb.
7 1, 1933, and within the six months last past.

Wherefore the Plaintiffs pray this Honorable Court:

First, to adjudge and decree that the Plaintiff, Harold A. Wheler, is the true, first, original and sole inventor of the improvements set forth in the said claims Nos. 68, 69, 72 to 77, inclusive, hereinabove recited;

Second, to adjudge and decree that Plaintiff, Hazeltine Corporation, as assignee of said invention and of said application, Serial No. 203,879, is entitled, according to law, to receive a patent for the invention specified in and covered by said claims Nos. 68, 69, 72 to 77, inclusive, or for any part thereof, as the facts in the case may appear;

Third, to authorize and direct the Commissioner of Patents to issue to the Plaintiff, Hazeltine Corporation, Letters Patent of the United States, as assignee thereof, embodying said claims Nos. 68, 69, 72 to 77, inclusive, upon the filing in the U. S. Patent Office of such adjudication, and upon compliance with the requirements of law in such cases made and provided;

Fourth, that the Plaintiffs have such other and further relief as may be just and proper.

HAROLD A. WHEELER,
HAZELTINE CORPORATION,
By JOHN R. BINNS,
Treasurer.
CLARENCE M. FISHER,
Solicitor for Plaintiffs.

WILLIS H. TAYLOR, JR.,
Of Counsel.

STATE OF NEW YORK,
County of New York, ss:

8 John R. Binns, being duly sworn, deposes and says that he is a resident of Brooklyn, County of Kings, State of New York, and is Treasurer of Hazeltine Corporation, one of the Plaintiffs named in the foregoing Bill of Complaint; that he has read the foregoing Bill of Complaint and knows the contents thereof, and that the same is true of his own knowledge, except as to matters therein stated to be alleged upon information and belief, and as to those matters he believes it to be true.

JOHN R. BINNS.

Subscribed and sworn to before me this 30th day of June, 1933.

[SEAL.]
GRACE T. PROSSER,
Notary Public, New York County.

N. Y. Co. Clerk's No. 125, Reg. No. 5P19.
Commission expires March 30, 1935.

Answer to the Bill of Complaint.

Filed July 15, 1933.

* * * * * * *

To the Honorable the Judges of the Supreme Court of the District of Columbia.

Conway P. Coe, Commissioner of Patents, defendant herein, in answer to the Bill of Complaint alleges on information and belief as follows:

1. He admits the allegations of residence and citizenship of the parties to this suit.

2. He admits the allegation of jurisdiction under Section 4915 R. S.; 35 U. S. C. A. 63.

3. He has no information as to the allegations of invention and the non-existence of statutory bars except as informed by the Bill and by the application thereinafter referred to.

9 4. He admits that plaintiff Harold A. Wheeler on July 7, 1927, filed an application for letters patent in the United States Patent Office to which Serial No. 203,879 was given.

5. He admits the allegations of assignment.

6. He admits that the application was duly prosecuted, and that the claims recited in paragraph 6 were finally rejected by the primary examiner upon the following prior art:

Friis, 1,675,848, July 3, 1928;
Perry, 1,536,130, May 5, 1925.

Profert of copies of these patents is hereby made. He admits that appeal was taken to the Board of Appeals, which Board of Appeals rendered a decision on February 1, 1933, affirming the decision of the primary examiner. Defendant denies that the action of these tribunals was erroneous. He denies that plaintiffs are entitled to these claims as they are held to be unpatentable over the prior art cited, as more fully appears from the statement of the examiner and the decision of the Board of Appeals, copies of which will be presented at the hearing, together with copies of the decision of the Examiner of Interferences dated July 31, 1931, and the decision of the Board of Appeals dated February 26, 1932, in which claims presented in Interference No. 60,839 were held unpatentable on a motion to dissolve and a motion to add claims.

6 (a) He admits that certified copies should be furnished as offered in paragraph 6 (a).

7. He admits the allegations paragraph 7 make in support of jurisdiction.

Further answering defendant denies each and every allegation of the Bill of Complaint not herein specifically and sufficiently denied or admitted, and prays that plaintiffs' Bill of Complaint be dismissed.

Wherefore defendant having fully answered the Bill of Complaint denies that plaintiffs are entitled to the relief demanded or any part thereof and prays that he be hence dismissed with all costs of the proceedings against the plaintiffs as provided in Section 4915 R. S.

CONWAY P. COE,
Commissioner of Patents, Defendant.
T. A. HOSTETLER,
Solicitor of the U. S. Patent Office,
Attorney for Defendant.

DISTRICT OF COLUMBIA,
City of Washington, ss:

I, Conway P. Coe, Commissioner of Patents, depose and say that I have read the above answer by me subscribed and know the contents thereof, and that the statements of facts therein made as upon personal knowledge are true, and those made upon information and belief I believe to be true.

CONWAY P. COE,
Commissioner of Patents.

Subscribed and sworn to before me this 14th day of July, 1933.

[SEAL.] ALBERT W. KAISER,
Notary Public, D. C.

My commission expires March 21, 1938.

Findings of Fact.

Filed July 9, 1935.

* * * * * * *

1. The application of the plaintiff Wheeler, filed July 7, 1927, discloses a radio receiver wherein the volume emitted by the loudspeaker is maintained at a nearly constant level by the use of a circuit which automatically varies
11 the amplification of certain stages in inverse ratio
to the strength of the received signal, and having a resonance indicator connected in the circuit to aid in tuning.

2. The patent to Friis, 1,675,848, (application filed November 29, 1924, patent issued June 3, 1928) and the British patent of the Western Electric Company, No. 259,664, which is substantially identical therewith, disclose apparatus for maintaining the output of a receiver substantially constant despite fluctuations in the strength of received signal.

3. The patent to Affel, 1,574,780, (application filed October 5, 1921, patent issued March 2, 1926) discloses a system wherein the amplification of an amplifier is varied in accordance with the strength of incoming signals.

4. The patent to Perry, 1,536,130, (application filed March 29, 1924, patent issued May 5, 1925) discloses a combined transmitter and receiver wherein a resonance indicator is used to aid the operator in tuning the apparatus.

5. The patent to Heising, 1,823,360, (application filed July 6, 1925, patent issued September 15, 1931), relates to a radio receiver wherein the output is maintained constant despite fluctuations in received signal strength in combination with a resonance indicator.

Conclusions of Law.

1. The claims are unpatentable over the prior art adduced by defendant.

2. It was not an act of invention to put the resonance indicator disclosed in the patent to Perry, 1,536,130, in the circuit of the Friis patent, No. 1,675,848.

3. It was not an act of invention to put the resonance indicator disclosed in the patent to Perry, 1,536,130, in the circuit of the Affel patent, No. 1,574,780.

4. The use of a resonance indicator in such a combination as claimed by the plaintiff Wheeler was not new with him, as is shown by the Heising patent, No. 1,823,360. 12

5. Plaintiff is not entitled to an allowance of the claims and the Bill will be dismissed.

F. DICKINSON LETTS,
Justice.

July 9th, 1935.

Final Decree.

Filed July 9, 1935.

* * * * * * *

This cause having come on to be heard and having been tried in open court and argued by counsel for the respective parties upon the pleadings and proofs adduced and submitted to the Court,

It is adjudged, ordered and decreed this 9th day of July, 1935, that the Bill of Complaint in this case be, and the same hereby is dismissed with costs against the plaintiff.

F. DICKINSON LETTS,
Justice.

Petition for Appeal.

Filed July 10, 1935.

* * * * * * *

Hazeltine Corporation and Harold A. Wheeler, Plaintiffs in the above-entitled cause, conceiving themselves to be aggrieved by the decree of this court made and entered in this cause on the 9th day of July, 1935, do hereby appeal from said decree to the United States Court of Appeals for the District of Columbia, and pray that their appeal may be allowed.

HAZELTINE CORPORATION,
HAROLD A. WHEELER,
By CLARENCE M. FISHER,
Their Attorney.

13 *Order Allowing Appeal.*

The foregoing petition for appeal having been duly filed in this cause, it is hereby ordered that the same be and it hereby is allowed and that the Plaintiffs file a bond for costs pending appeal in the sum of Fifty Dollars ($50.00) in cash.

JAMES M. PROCTOR,
Justice.
Supreme Court of the District of Columbia.

Washington, D. C., July 10, 1935.

Citation.

Issued July 10, 1935.

* * * * * * *

The President of the United States of America to Conway P. Coe, Commissioner of Patents, Greeting:

You are hereby cited and admonished to be and appear at a Court of Appeals of the District of Columbia, upon the docketing the cause therein, under and as directed by the Rules of said Court, pursuant to an Appeal noted in the Supreme Court of the District of Columbia, on the 10″ day of July, 1935, wherein Hazeltine Corporation and Harold A. Wheeler are Appellants, and you are Appellee, to show cause, if any there be, why the Decree rendered against the said Appellants, should not be corrected, and why speedy justice should not be done to the parties in that behalf.

Witness the Honorable Alfred A. Wheat, Chief Justice of the Supreme Court of the District of Columbia, this 10″ day of July, in the year of our Lord one thousand nine hundred and Thirty-five.

[SEAL.] FRANK E. CUNNINGHAM,
Clerk.
By HARRY M. HULL,
Assistant Clerk.

Service of the above Citation accepted this 10″ day of July, 1935.

R. F. WHITEHEAD,
Attorney for Appellee.

14 *Memorandum.*

July 17, 1935—$50 deposit in lieu of Bond on Appeal.

Assignment of Errors.

Filed August 1, 1935.

* * * * * * *

The Plaintiffs, Hazeltine Corporation and Harold A. Wheeler, in support of their appeal, assert that this Court erred in the following respects, to wit:

1. In finding claims Nos. 68, 69 and 72-77, inclusive, of the application of Harold A. Wheeler, Serial No. 203,879, filed July 7, 1927, unpatentable over the prior art adduced by the Defendant.

2. In failing to find that Plaintiff Harold A. Wheeler is the true, first, original and sole inventor of the improvements set forth in the said claims Nos. 68, 69 and 72-77, inclusive, or any of them.

3. In failing to adjudge and decree that Plaintiff Hazeltine Corporation, as assignee of said invention and said application, Serial No. 203,879, is entitled to receive a patent for the invention specified in and covered by said claims Nos. 68, 69 and 71-77, inclusive, or any of them.

4. In failing to authorize and direct the Defendant to issue to Plaintiff Hazeltine Corporation, as assignee thereof, Letters Patent of the United States embodying said claims Nos. 68, 69 and 72-77, inclusive, or any of them.

5. In finding that the second Finding of Fact submitted by the Court is supported by the record.

6. In finding that the third Finding of Fact, sub-
15 mitted by the Court is supported by the record.

7. In finding that the fourth Finding of Fact submitted by the Court is supported by the record.

8. In finding that the fifth Finding of Fact submitted by the Court is supported by the record.

9. In finding that it was not an act of invention to put the resonance indicator disclosed in United States Letters Patent No. 1,536,130, to Perry, in the circuit of United States Letters Patent No. 1,675,848, to Friis, or in the corresponding circuit of British patent No. 259,664.

10. In failing to find that the combination of the aforesaid Perry and Friis patents does not anticipate the said claims 68, 69 and 72-77, inclusive, of said Wheeler application.

11. In finding that it was not an act of invention to put the resonance indicator disclosed in United States Letters Patent No. 1,536,130, to Perry, in the circuit of United States Letters Patent No. 1,574,780, to Affel.

12. In failing to find that the combination of the aforesaid Perry and Affel patents does not anticipate the said claims 68, 69 and 72-77, inclusive, of said Wheeler application.

13. In finding that the use of a resonance indicator in a combination such as claimed by Plaintiff Wheeler was not new with him, but is shown by United States Letters Patent No. 1,823,360, to Heising.

14. In failing to find that the use of a resonance indicator in a combination such as claimed by Plaintiff Wheeler was new with him and was not shown by the aforesaid Heising patent.

15. In failing to find that, as a conclusion of law, United States Letters Patent Nos. 1,675,848, to Friis, 1,574,780,
to Affel, and 1,823,360, to Heising, having issued
16 after Wheeler's successful demonstration in Jan-
uary 1926, cannot be considered as illustrating the state of the art publicly available prior to that time, and that, since they do not disclose the Wheeler combination, they are not material to the issue of the patentability of claims which define Wheeler's combination.

16. In failing to find that, as a conclusion of law, the effective date of British Letters Patent No. 259,664, to Western Electric Co., corresponding to the aforesaid Friis patent, is the sealing date, January 12, 1927; and that, inasmuch as this date is subsequent to the date of Wheeler's successful demonstration, the disclosure of this patent is not material to the issue of patentability herein.

17. In holding that the Conclusions of Law submitted by the Court, or any of them, sustain the decree herein.

18. In dismissing the Bill of Complaint.

19. In failing to grant the prayers of the Bill of Complaint.

CLARENCE M. FISHER,
Solicitor for Plaintiffs.

Dated August 1, 1935, Washington, D. C.

Supreme Court of the District of Columbia.

Thursday, August 1, 1935.

The Court resumes its session pursuant to adjournment, Mr. Justice Letts, presiding.

* * * * * * *

Come now the parties hereto by their respective attorneys of record, and thereupon, the plaintiff by its attorneys presents to the Court its Statement of Evidence taken at the trial of this cause, and prays that the same be 17 signed and made of record, nunc pro tunc, which is hereby accordingly done.

Designation of Record.

Filed July 26, 1935.

* * * * * * *

To the Clerk of the Supreme Court of the District of Columbia:

You are hereby requested to certify the transcript of record and proceedings in the above-entitled cause to be filed in the United States Court of Appeals for the District of Columbia for use in the appeal heretofore allowed, and to include in such transcript the following items, said items being considered sufficient for the determination of the questions raised on appeal, namely:

1. Bill of Complaint.
2. Answer.
3. Statement of Evidence including Approval by the Court (Without Caption).
4. Plaintiffs' Exhibits Nos. 1, 2, 3, 4, 6A, 6B, 6C and 8.
5. Defendant's Exhibits Nos. A, B, F, G, H, I and J.
6. Defendant's Findings of Fact and Conclusions of Law (Without Caption).
7. Final Decree (Without Caption).
8. Petition for Appeal and Order Allowing the Same (without Caption).
9. Citation of Appeal (without Caption).
10. Docket Entry showing cash deposit in lieu of Appeal Bond.

11. Assignment of Errors (without Caption).

12. This Designation of Record, with Clerk's Certificate (without Caption).

CLARENCE M. FISHER,
Solicitor for Plaintiffs.

Dated July 26, 1935, Washington, D. C.

18 Service of the foregoing Designation of Record acknowledged this 26th day of July, 1935.

R. F. WHITEHEAD,
Solicitor for Defendant.

19 Supreme Court of the District of Columbia.

United States of America,
District of Columbia, ss:

I, Frank E. Cunningham, Clerk of the Supreme Court of the District of Columbia, hereby certify the foregoing pages numbered from 1 to 18, both inclusive, to be a true and correct transcript of the record, according to directions of counsel herein filed, copy of which is made part of this transcript, in cause No. 55874 in Equity, wherein Hazeltine Corporation, and Harold A. Wheeler are Plaintiffs and Conway P. Coe, Commissioner of Patents, is Defendant, as the same remains upon the files and of record in said Court.

In testimony whereof, I hereunto subscribe my name and affix the seal of said Court, at the City of Washington, in said District, this 21st day of October, 1935.

[Seal Supreme Court of the District of Columbia.]

FRANK E. CUNNINGHAM,
Clerk.

By CHAS. B. COFLIN,
Assistant Clerk.

20 In the Supreme Court of the District of Columbia.

In Equity.

No. 55,874.

HAZELTINE CORPORATION and HAROLD A. WHEELER,
Plaintiffs,

vs.

CONWAY P. COE, Commissioner of Patents, Defendant.

Statement of Evidence.

At the hearing of the above-entitled cause beginning on Thursday, February 28, 1935, before Mr. Justice F. Dickinson Letts, the following proceedings were had and evidence offered on behalf of the parties hereto.

Thereupon, to maintain the issues on his part joined, the Defendant offered the following exhibits which were marked for identification:

"Defendant's Exhibit A," Friis patent No. 1,675,848.

"Defendant's Exhibit B," Perry patent No. 1,536,130.

"Defendant's Exhibit C," prints of drawings of Wheeler application.

"Defendant's Exhibit D," Examiner's statement.

"Defendant's Exhibit E," decision of Board of Appeals on Ex Parte appeal.

"Defendant's Exhibit F," decision of Examiner of Interferences on motion to dissolve and motions to amend, in interference No. 60,839, Simonds v. Wheeler.

21 "Defendant's Exhibit G," decision of Board of Appeals in interference No. 60,839, Simonds v. Wheeler.

"Defendant's Exhibit H," Heising patent No. 1,823,360.

"Defendant's Exhibit I," Affel patent No. 1,574,780.

Thereupon, to maintain the issues on their part joined, Plaintiffs offered in evidence the following:

Harold A. Wheeler, being called as a witness on behalf of the Plaintiffs and having been first duly sworn, testified as follows:

Direct examination.

By Mr. Guild:

The Witness: I am the Harold A. Wheeler named in application Serial No. 203,879, here involved, and am in charge of the Bayside laboratory of the Hazeltine Corporation. The laboratory is located at Bayside, Long Island, New York. I have been employed by the Hazeltine Corporation since 1924, when the corporation was formed. The laboratory is occupied in developing improvements in radio receivers and apparatus directly related thereto. Almost all of our work is directed to the improvement of radio broadcast receivers, such as are sold commercially for use by the general public, and that has been true ever since my connection with the corporation.

My education and experience in the radio field are as follows: I attended George Washington University here in Washington during the years 1921 to 1925. I received in 1925 the degree of Bachelor of Science in physics. From there I took some post graduate work at Johns Hopkins University, in the physics department. This work
22 occupied a good share of my time from 1925 to 1928. While at Johns Hopkins University I was also employed as lecturer, giving lectures to post graduate students in the physics and electrical engineering departments on the subject of radio vacuum tubes such as are universally employed in radio broadcast receivers.

I was at Johns Hopkins in years which were also included in the time of my employment by the Hazeltine Corporation. I came in contact with the Hazeltine Corporation at the time of its formation, because of previous contractual relations with Professor Hazeltine, and beginning in 1924 I was retained by the Hazeltine Corporation to devote whatever time I had available to them, outside the studies I was pursuing in the universities. During the years 1924 to 1927, the time I devoted to the work of Hazeltine Corporation was mostly in the summer vacation, but beginning with the summer of 1928, and up to the present time, I have been employed continually in the work of Hazeltine Corporation. During the years 1921 to 1922 I was employed during the summers at the radio laboratory of the United States Bureau of Standards. I was also employed half time during the intervening winter in the same place. The work there related mostly to the testing of radio receivers which were then proposed for radio broadcasting. Radio broadcasting was then in its infancy.

Professor Hazeltine's relation to the Hazeltine Corporation at the time of my first employment with Hazeltine Corporation was as the inventor of patents which formed the basis for the original work of the Hazeltine Corporation, and he was closely connected with the work of the corporation at that time, at the time it was founded.

23 I am a member of the Institute of Radio Engineers, and I have served on the board of directors of that Institute. I have also done a great deal of work on the various committees of the Institute of Radio Engineers, largely relating to radio broadcasting. I am chairman and have been for several years chairman of the technical committee on radio receivers of that Institute. The work of this committee is outlining standardized test procedures and generally studying the performance of radio broadcast receivers. In connection with my studies in the radio art I have made a particular effort to acquaint myself with publications. Since about 1916, when I first took an active interest in radio, with a view to following it as a profession, I have tried to keep continually in touch with the development of the art by way of reading publications and devoting a great deal of thought to the subject. I am now in charge of the laboratory at Bayside, Long Island. We have a staff of about 10 graduate engineers in that laboratory. I am responsible for directing their researches in the field of radio broadcast receivers and closely related problems. The purpose of developing these receivers is to offer the designs for manufacture by the licensees of Hazeltine Corporation. The corporation's business is based on licensing most of the radio broadcast receiver manufacturers under its patents, and the work of the laboratory is, on the one hand, the building up of the patent situation, and on the other hand, assisting our licensee manufacturers in every way to exploit the improvements which we develop. Naturally this involves assisting them not only in the design of receivers, but even as far as assisting them in the production of receivers in any way we can.

24 In this chart, Plaintiff's Exhibit No. 1, just handed to me, I have divided the radio receiver in the upper

diagram into four essential parts. The parts are called, respectively; Radio-frequency carrier-current amplifier; detector; audio-frequency modulation-current amplifier, and loudspeaker. The signal received on the antenna has a high frequency of oscillation, and this signal is first amplified in the radio-frequency amplifier to make it strong enough to be detected by the detector. The detector serves the function of converting these very high-frequency oscillations of the received signal to a lower frequency of waves that are of such frequency that they can be heard when reproduced on the loudspeaker. In other words, it converts the radio-frequency currents to what we call audio-frequency currents, the latter being of such frequencies as lie within the range of audibility of the ear.

The Court: I used to know what frequency meant. I am not sure that I do now.

The Witness: Frequency, as applied to alternating current, in general denotes the number of reversals, of complete cycles of reversal, of that current per second. Alternating current is the general term applied to all sorts of currents which reverse periodically in time. A radio frequency is a very high frequency. The currents reverse themselves on the order of one million times per second. The frequency is so high that if waves of that frequency are produced in the air they are entirely inaudible, but electrical waves of that frequency produced in the ether can be transmitted with great facility. Then the audio frequency is still a pretty high frequency, but it is relatively low. The alternating currents with frequencies on the order of 30 to 10,000 cycles per second are within the audible range.

The Court: When you said "thirty" did you mean 30,000?

The Witness: No; thirty cycles up to 10,000 cycles.

25 The Witness: The waves which carry the most of the sound in speech are on the order of 100 to 4,000 cycles per second, mostly in the neighborhood of 200 to 400 cycles. These sound waves of speech are audio-frequency waves.

After the detected signal currents are amplified in the audio-frequency amplifier, they are in shape to be reproduced in the air as sound. That is, they are sufficiently intense, and they are of the proper frequencies, to actuate a loudspeaker and produce sound in the air corresponding to the original sound which was transmitted on the radio signal.

Diagrammatic chart was marked "Plaintiffs' Exhibit No. 1" and received in evidence.

The Witness: Referring to the box in Plaintiffs' Exhibit No. 1 labelled "Radio-frequency amplifier", the specific object of that amplifier is the amplification of the relatively weak radio signals received on the antenna to such a degree that they are strong enough to be detected by the detector. That is, they have to be amplified before they are sufficiently strong, in many cases, to actuate a detector. The circle with the arrows on it, below the radio-frequency amplifier, is labelled "manual volume control". The function of that device is to enable the operator of the receiver, to enable the broadcast listener, to control the amount of amplification of the received signal. The purpose of this control is to amplify the signal just the right amount to operate the detector to best advantage, and to produce the right amount of sound from the loudspeaker as a result.

That is an old device.

26 The Court: That is the little buttom that we turn with our hands, is it?

The Witness: Yes. It is usually labelled "volume control" now, or some such designation. In the type of receiver which was common before 1928, say, this volume control knob was almost always employed in connection with the radio-frequency amplifier, and for the purpose that I mentioned, namely, to adjust the amplification of the signal so that the amplified signal delivered to the detector would be at the proper intensity.

The Witness: The radio-frequency amplifier has amplification as only one of its functions. The other function which is performed by that amplifier is that of selecting a desired signal from among all the signals which are present in the air. This selecting operation is accomplished by making the amplifier tunable to the desired signal. That is, we put in the amplifier a number of electrical circuits which are highly responsive to a certain frequency but relatively unresponsive to other greater or lesser frequencies. For a minute let us consider this problem of selectivity in terms of different stations. Different transmitters transmit on different frequencies. As far as the user is concerned, if he did not have this selection, he would have no way of tuning in any particular signal he desires to hear, and at the same time excluding from his receiver all the other signals which he does not wish to hear.

In the practical operation of a radio receiver—and I am thinking of it now just from the operational point of view—as the user manipulates it in the type of receiver illustrated in the upper diagram on Exhibit 1, there is a relation of use between the selectivity I have just been talking about and this manual volume control, in the sense
27 that the user must manipulate both controls in order
to tune in and receive any one desired signal, or another desired signal. In the operation of the receiver the user manipulates these controls together somewhat as I can describe in a few words. If he hears no signal, he will turn up his volume control knob to increase the amount of amplification, and try to pick up some indication of a signal, and at the same time he is likely to manipulate the tuning adjustment to try to find a station on the tuning dial which he desires to listen to. Once having heard the station he wants, he has to proceed to tune in that station as exactly as possible, and that operation comprises turning the tuning dial in the direction in which the signal comes in louder and then, when the signal gets a little louder, he has to back off on the volume control knob to keep from blasting in his loudspeaker, and tune it a little closer. Then he has to back off on the volume control knob again, and continue that operation until he finds a point of adjustment of the tuning dial corresponding to greatest sensitivity toward this particular transmitter, and there he leaves the tuning dial set and makes the final adjustment on his manual volume control, according to how loud he wishes to hear the signal.

In the operation of this receiver, if the operator wanted to tune from the station I have described to another one, he would have to turn his tuning dial to another part of the scale and repeat the same procedure. If the second station he desired was weaker than the first, he would have to turn up the volume control knob to obtain a great deal more amplification. If the second signal happened to be
28 stronger than the first, then, as he tuned toward the
second signal, he would meet a tendency for his loud-

speaker sound to be much too loud, which we call blasting, and he would have to back off on the volume control knob accordingly as he varied his tuning adjustment.

As the user varies this tuning adjustment, he knows that he is in tune with the station when he arrives at the point on the tuning dial where any further adjustment either side of that point decreases the loudness; then he leaves his dial adjusted approximately at that point, as nearly as he can determine by ear. In order to obtain that maximum loudness at a reasonable level, he has to already have set the volume control knob at approximately the right position. That manipulation is what is known as tuning by ear.

Now, considering the signals that come in from the different stations to which a user might want to listen, the signals from different stations, as they arrive on the antenna of a receiving station, are widely different in strength. The amount of difference is on the order of a ratio of a thousand times, or more, between the signal intensity of a strong or local station, and that of a relatively weak or distant station. Because of the difference in received signal intensity or strength, the operator has to manipulate the volume control knob while he is listening, to get the desired amount of sound on a signal of any intensity within that wide range of intensities. In other words, he manipulates the volume control knob to make up for the difference in the signal strength.

The difference in signal strength between different stations is not the only difference in signal strength
29 noted on a radio receiver. There is another effect, which is referred to as fading. That is the slow or rapid fluctuation of signal strength of a certain station as received at some distant point. The fading is caused by changes in the condition of the air and of the ether near the surface of the earth that occur between the transmitting station and the receiving station. There is nothing that a radio listener can do to this intervening ether, or whatever causes these fading conditions. He cannot avoid the existence of fading, it is from natural causes. There is nothing practical that can be done in this kind of a receiver that I have been referring to, in the upper part of Exhibit No. 1, to counteract that fading to any degree. The only thing a listener could do would be to sit by the receiver and con-

stantly adjust the manual volume control knob in a manner which would be a great nuisance. It is not practical.

The general representation of a radio receiver as shown in the upper figure of Plaintiffs' Exhibit 1 is typical of almost all the receivers which were manufactured and sold for broadcast use in the period from about 1924 to 1928. Naturally, there is not any definite boundary for that period, but this receiver was typical of that period and of the great majority of receivers sold in that period. My work at the laboratory of the Hazeltine Corporation had to do with receivers of the general nature of that shown in the upper diagram of Plaintiffs' Exhibit No. 1. In connection with my development work at the Hazeltine Corporation laboratory, and aside from the general work of improving this type of receiver, I attacked the problem more specifically of simplifying the manipulation of the controls of the receiver to make it more acceptable for a broadcast listener's use. The tuning control was an absolutely essential control in some form. It could not be eliminated, although we did a great deal of work to simplify the tuning operation in one way or another. The volume control adjustment appeared to me to be a control that could be greatly simplified, because the user performed almost identically the same process with that knob every time he tuned in a station, and the more skillful the listener was the more carefully he performed this process. I considered that this process could be greatly simplified, or possibly performed entirely automatically.

The difficulty in tuning the receiver by ear, as I described, was the nuisance, which, of course, was a great impediment. The difficulty of exact tuning was just about proportional to the lack of experience of the operator. A skilled operator could tune a receiver by ear very close to the exact tuning point, but an unskilled listener was able only to tune the receiver approximately. He tuned it near enough so he could hear his signal, and if he had a particular interest in careful operation of the receiver, then naturally he would be more careful and tune it closer to the correct point. I made an effort to improve the receiver so that it would be easier to tune and overcome the difficulties just mentioned; that was part of the general problem I was working on, to facilitate the operation of the set.

I was working on the problem about the middle of 1925; that is the date I would set as definitely tackling this problem. At that time I was working at the laboratory of the Hazeltine Corporation, which was then located in Hoboken, New Jersey, at Stevens Institute. I continued studying this problem when I returned to Johns Hopkins University in the fall of 1925. In fact, I spent a great part of my spare time on this problem.

31 After turning over in my mind what I considered to be several possible arrangements for automatically facilitating the operation of the set, I finally decided to build a receiver and try out one or more of these arrangements.

(Noon Recess.)

The Witness: This receiver was built in my home workshop, at my home in Chevy Chase in Washington, and it was built along the lines of an experimental model, assembled on a table in my workshop. The most interesting feature of this receiver was the automatic volume control with a visual tuning meter. I can describe this feature in a little more detail with reference to Plaintiffs' Exhibit No. 1. The lower diagram on the chart shows the same four essential parts of the radio receiver, but it is modified, in that the manual volume control is replaced by other apparatus. The four essential parts of the radio receiver were the same as in the upper diagram, namely: the radio-frequency carrier-current amplifier; detector; audio-frequency modulation-current amplifier; and loudspeaker.

The new receiver had a new circuit arrangement, or new circuit arrangements, to which I have already referred as automatic volume control with a tuning meter. The function of the automatic volume control was to control automatically the amount of amplification in the radio-frequency amplifier and to have this automatic control actuated by the signal itself. The arrangement used the detector and a connection from the detector back to the radio-frequency amplifier. The operation of this arrangement utilized the signal voltage produced in the detector and applied this voltage back to the radio-frequency amplifier, to

32 automatically reduce its amplification with increasing signal strength. That is, as far as the user was concerned, this automatic control performed the main func-

tions which the user had been accustomed to performing manually by means of the manual volume control.

I should compare the operation of the automatic volume control with the most highly skilled operation of the manual volume control. That is, the automatic operation did everything that a highly skilled operator could do if he properly manipulated the manual volume control, but it did not require any attention. The operation was automatic and was accomplished without any attention on the part of the user. This automatic control made the tuning very much easier, because the user no longer had to worry about the manipulation of the volume control while he was tuning the receiver to one station or another. He could devote all his attention, and devote all his skill of operation, to the tuning dial alone.

A visual tuning indicator was installed in the receiver at the same time I was perfecting the automatic volume control feature, and it was connected in such a place as to be actuated by the automatic volume control, so as to give an indication which would be very useful to the operator in the operation of the receiver. The meter, as an aid in operating the receiver, behaved like this: The user, tuning the receiver to a dial setting approximately corresponding to the station he wants to hear, found that listening to the loudspeaker did not give him a satisfactory means or a satisfactory method of tuning accurately to the signal and determining when he was properly in tune. By observing
the meter as I had it connected in the circuit, I found
33 it possible to tune the receiver much more accurately
than I had previously done by ear in the older types of receiver and obtained a more positive indication when the receiver was properly tuned.

As the receiver was tuned to a signal, the pointer on the meter would swing in the direction indicating less current in the meter, and when the receiver was exactly tuned to the desired signal, the pointer on the meter would swing farthest in the direction of reducing current in the meter, so that even an unskilled operator watching the meter would have no difficulty in tuning the receiver very accurately to the signal. That is, as you sweep the dial toward the correct position, when you are in tune with a station, the meter pointer moves in the direction of lowest current in the meter. Then, when you are exactly in tune, the meter indicates, by the pointer swinging farthest in the direction of least current in the meter. That is, the pointer indicates minimum current when the tuning is exactly correct, and that minimum is quite easily observed. By "easily observed" I mean that if you move the tuning dial just the least little bit away from where it should be, the meter gives a sudden motion to indicate it.

On the lower diagram on Plaintiffs' Exhibit No. 1 there is a meter labelled "Amplifier Meter", which I have been referring to as the tuning meter. It was connected in the plate or anode circuit of one of the vacuum tubes in the amplifier, and it indicated the amount of current flowing through the space in that tube. The relation of the current actuating that meter, as I connected it, to the tuning, was that, as the radio-frequency amplifier was tuned to the signal, closer and closer, the tuned circuits in
34 the amplifier responded to a greater extent to the signal, and the automatic control correspondingly reduced the amount of amplification in the vacuum tubes. The total amount of amplification in the amplifier depended both on the tuned circuits and on the vacuum tubes in the amplifier.

When I say it depended upon the tuned circuits, I mean it depended upon the adjustment of the circuit as to whether or not it was tuned to the signal. It also depended on the vacuum tubes and on the automatic control of those vacuum tubes by the detector. When you are tuning to a certain signal, the automatic control has the effect of adjusting the amplification in the amplifier so that the amplified signal which reached the detector would be approximately at a predetermined intensity, so that tuning the amplifier to a signal tended to increase the amplified signal and the detector and the automatic control circuit reacted to that tendency by decreasing the amplification in the vacuum tubes of the amplifier.

This meter, then, was connected in a part of the receiver which was under the influence or control of this automatic control circuit; it was connected in the plate circuit or anode circuit of a vacuum tube which was subject to the automatic control from the detector. The meter, then, being connected in the automatically controlled part of the receiver, measured or indicated the amount of control being employed at any given time. The amount of control caused a certain amount of reduction in the plate current of the vacuum tube or vacuum tubes which were subjected to the control, and this meter, measuring that plate current, therefore indicated less and less current as the amplification was reduced more and more by the automatic control action.

35 The indicating meter connected in this amplification control part of the system is related, in its response, to the strength of the signals received on the receiver as they come in from outside. Once having tuned in a signal, the automatic control regulates the amount of amplification in the radio-frequency amplifier to just the sufficient amount required to amplify that signal and actuate the detector, so that if the signal is greater the automatic control reduces the amplification, and that is manifested by a reduction in the current through the meter, and the meter indicates accordingly. On the other hand, if the signal is relatively weak, the automatic control will permit a relatively greater amount of amplification, and that is manifested by greater current indicated on the meter.

As a practical matter, as the user would look at the receiver as he is operating it, perhaps not knowing about just where the meter was connected, he would observe that the indication of the meter when the receiver is tuned gives a relative indication of the strength of the received signals in this matter. The less current indicated on the meter means greater signal strength, and vice versa. If the meter reading fluctuates while the receiver is tuned to a given signal, that is an indication of fading; and there, again, greater current through the meter indicates that the signal is being weakened by fading, and vice versa.

The automatic amplification control in large measure overcame the effects of fading by compensating for it; the effects of fading, as far as they were audible to the listener, were greatly reduced. They were reduced to the point where they were not noticeable by listening to the loudspeaker. While this phenomenon, which was taking
36 place with the swinging up and down of the signal strength, was not noticeable any longer in the loudspeaker, it was noticeable from the meter. That is substantially the only way that the listener could tell when the signal was fading, by observing the meter.

I did not have to compensate between strong and weak stations. The automatic control actuated the meter on signals of any strength or signals of any intensity, over a wide range of intensities, so that the user had before him at all times a direct indication of the relative signal strength, without manipulating any auxiliary control, or without going through any complex operation. He merely had to observe the meter.

After I had this receiver which I have just described in operation, I demonstrated it to a lot of my friends from time to time. There was one occasion in particular, when I had a group of friends I was entertaining at my home in Chevy Chase, where I was working on this, on an evening early in January, 1926. Several of my friends who were present were either physicists or electrical engineers, who were very much interested in radio broadcast receivers, so I demonstrated the receiver to them and I explained the operation of the automatic volume control with the tuning meter, and demonstrated the operation of the tuning meter on receiving various stations. Mr. Vernon E. Whitman was present on that occasion and was included in this group which were familiar with radio receivers in general. He was working, or had been working, at the Bureau of Standards on electrical instruments and aeronautic instruments, and he had also built various radio broadcast receivers at
his own home. He, incidentally, was my roommate
37 at Johns Hopkins University and was taking gradu-
ate courses at the same time, so we discussed radio
a great deal.

This work I have been describing was done at home during the Christmas holidays, and I had to return to Johns Hopkins University presently. Then I got in touch with the Hazeltine Corporation engineers very shortly, and soon after arranged to demonstrate the receiver to one or more of the other engineers in the Hazeltine Corporation. The intention I had was to put these improvements into commercial use in broadcast receivers as soon as possible. I went on and designed commercial receivers and in the summer of 1926 I instructed the Stromberg-Carlson Company, in Rochester, New York, on the assembly of a broadcast receiver embodying these improvements. I gave them instructions on the occasion of a trip to Rochester, to their factory. The Stromberg-Carlson Company was one of the Hazeltine licensees. The receiver which I gave the Stromberg-Carlson Company instructions to build was built by them promptly and sent to our laboratory in Hoboken for me to test its operation. I received the set they had built and tested its operation and found that the automatic volume control with the visual resonance indicator was operating quite successfully, quite in accordance with my previous experiments at home, and I demonstrated the operation of this Stromberg-Carlson receiver to one or more of their engineers, and also to other engineers of our own company and of other licensee manufacturers. This Stromberg-Carlson model included the automatic volume control with the tuning meter; the same general arrangement for that purpose as I had used in the receiver I had built previously at my home.

38 I published an article of a scientific nature on this automatic volume control development with the indicating meter. It was a paper I prepared for presentation before the Institute of Radio Engineers. That was the recognized organization of radio engineers in this country. This paper I presented before a meeting of the Institute which was held in New York City in the early part of November, 1927. (Witness identifies as the paper just mentioned a copy of the Proceedings of the Institute of Radio Engineers, volume 16, January, 1928, No. 1, pages 30-34.

Proceedings of Institute of Radio Engineers, January, 1928, vol. 16, No. 1, pages 30-34, were marked Plaintiffs' Exhibit No. 2 and received in evidence.

Referring to my I. R. E. paper, Plaintiffs' Exhibit No. 2, I will point out where, in that paper, the specific features which we are discussing here are explained, namely, automatic amplification control with visual indicator. The paper as a whole is devoted to various problems connected with automatic volume control, and the more specific reference to the visual tuning indicator, or tuning meter, occurs on page 33, the paragraph beginning "In consequence of the automatic control action * * *". That paragraph refers to Figure 2. That is a circuit diagram of some parts of a receiver having automatic volume control with tuning meter. The meter is indicated by the designation "MA" and is connected in the plate circuit of a controlled amplifier tube in the manner I have described. The automatic volume control action takes place by virtue of the connection which is labelled "Automatic Grid Bias".

Figure 1 of my paper, Plaintiffs' Exhibit 2, has a general similarity to the lower diagram on Plaintiffs' Exhibit No. 1. The four main parts of the receiver, as shown in Figure 1, are labelled, respectively: "Neutralized 39 Tuned R. F. Amplifier; Rectifier and Filters; A. F. Amplifier; and Speaker". Then we see, in Figure 1, a block labelled "Manual Volume Control", which comes between the rectifier block and the A. F. amplifier block. The rectifier and filters, in Figure 1, perform the same function and refer to the same apparatus that I have called "Detector" in Plaintiffs' Exhibit No. 1. The A. F. amplifier in Figure 1 refers to the same apparatus I have called "Audio-frequency (modulation-current) amplifier", in Plaintiffs' Exhibit No. 1. The manual volume control interposed between these two in Figure 1 does not correspond to the manual volume control in the upper diagram of Plaintiffs' Exhibit No. 1, but rather performs a different sort of function. It does not have to be manipulated continually by the user.

The practical importance of including a manual volume control in a receiver such as I have been describing, that has the automatic amplification control feature, is that in such receiver it is used by the listener mainly to adjust the loudness, greater or less, according to his preference. It is not used for the purpose of compensating for wide differences in signal intensity, as was the manual volume control described with reference to the upper diagram in Plaintiffs' Exhibit No. 1.

Continuing the comparison of Figure 1 with Plaintiffs' Exhibit No. 1, the automatic grid bias in Figure 1 corresponds to the automatic volume control connection indicated in Plaintiffs' Exhibit No. 1. The amplifier meter is not indicated specifically in Figure 1, but is part of the neutralized tuned R. F. amplifier, which is shown more specifically in Figure 2. The visual indicator there is marked with a circle with an arrow through it, and beneath the letters "MA", in Figure 2.

40 This Institute of Radio Engineers paper, Plaintiffs' Exhibit No. 2, was the first publication, so far as I know, of this general arrangement of automatic volume control with tuning meter. The presentation of my In-

stitute of Radio Engineers paper on this subject was the subject of newspaper items published throughout the country about the time the paper was delivered, or about the time it appeared in the Proceedings of the Institute. One group of items appeared about November 1, 1927, and another group about January, 1928.

On page 34 of my Institute of Radio Engineers paper, Plaintiffs' Exhibit No. 2, there is a reference to a British patent, No. 259,664. I had that in mind when I said that this Institute of Radio Engineers paper was the first one that I knew of to disclose the subject matter we are here discussing, but I did not consider that that patent had disclosed that subject matter.

In the last paragraph of page 34 of Plaintiffs' Exhibit No. 2, there is mention of the Howard Radio Company, of Chicago. In the summer of 1927, shortly before I prepared the paper, I spent a good deal of time in the factory of the Howard Radio Company in Chicago. I was engaged in designing for them a de luxe radio receiver which was intended to embody as many advanced improvements as possible, and one of those improvements was the automatic volume control with visual tuning indicator. These receivers were manufactured and sold at a very high price.

These Howard receivers, as far as I know, were the first receivers to be manufactured and sold having the improvement we have been talking about, that is, automatic volume control with the tuning meter. That was late in 1927 or early in 1928. Since that time there have been a
41 great many receivers manufactured commercially.
The Stromberg-Carlson Company, that I mentioned before, manufactured a receiver following the general arrangement that had been used in the model they built according to my instructions, that I have mentioned. This receiver was put on the market about the middle of 1929, and made very good use of the automatic volume control with the tuning meter. These Stromberg-Carlson receivers operated in accordance with the description I have given in connection with my original experimental model that I built in Chevy Chase. A large number of our licensee manufacturers have incorporated these improvements in their receivers since that time, and are still doing so today.

The new results, which were obtained by this particular combination of apparatus which I have described namely, my automatic amplification control with the visual indicator, as combined in a radio receiver, can be divided under two headings, which aids in describing them. One of the new results was related primarily to the facilitating of the operation of the receiver, and the other was related primarily to giving the user a direct indication of relative signal intensities.

Under the subject of simplifying the operation of the receiver, the intention in using this arrangement is to enable the user to easily tune the receiver accurately to the condition where he gets the best possible performance from the receiver. This includes several of the main characteristics of the receiver. The benefits from tuning the receiver accurately by this indication include securing the maximum selectivity against interference; the best fidelity of reproduction or tone quality of which the receiver is capable; and also enables the user to adjust the receiver easily for greatest sensitivity.

42 The use of this visual meter assisted in obtaining benefits from the automatic control itself. By adjusting the receiver for greater sensitivity the automatic volume control action had the widest range of operation. For example, a signal whose intensity was fading might, at times, be very weak, and the adjusting of the receiver for maximum sensitivity assured the user that he would get the best possible automatic control action, as compensating for this fading. That is to say, if the receiver is tuned with great precision and accuracy, the user will receive the benefits not only which, in older forms, would have been obtained with correct tuning, but also the best advantage was obtained from the automatic control. All that is the result of tuning correctly. Referring now to the other new result of signal intensity indication, the older receivers, as exemplified by the upper diagram on Plaintiffs' Exhibit No. 1, had no means for indicating the signal intensity. The loudness of the signal, for example, was not so much an indication of signal intensity as it was of the setting of the volume control knob. There was no way that the user of such a receiver would have a direct indication of the signal strength.

There was no practical way, so far as I know, prior to this development of mine, by which it was possible for the user of any kind of a radio receiver to obtain a direct indication of the intensity of the signals being received.

In the laboratory receiver which I built in Chevy Chase I actually employed a small portable Weston model 280 milliammeter, which indicated currents on the order of a few milliamperes. It was an expensive form of meter from the standpoint of including such a meter in a broadcast receiver for commercial sale. Naturally, it was not an
43 extremely expensive laboratory type of meter. In
connection with further commercial developments, the Howard receiver, I mentioned, and the Stromberg-Carlson receiver, which was manufactured in 1929, both used meters which indicated about the same range of milliamperes, but were made in just slightly smaller and slightly cheaper style.

Later on, in the other commercial embodiments of this arrangement, this type of meter has been used in a great many receivers sold, and I believe it is still in use. There was an increasing demand, however, for a cheaper variety of meter which could be used in place of the more expensive types. This demand gave rise to the use of two or three other varieties of visual indicators, different from the usual form of meter.

All these different forms are operated in the same way by the receiver. They all give an extreme indication when the receiver is tuned in, and the same relative indication with differences in signal strength, and they are all used for the same purpose and in the same manner.

I have mentioned that this original meter which I used, and some of the commercial embodiments later, were milliammeters. When a listener is operating a radio receiver incorporating this arrangement, he is not concerned with the milliamperes that the meter happens to record. In the actual commercial embodiments of these tuning indicators it is not customary to calibrate the indicator in milliamperes, or amperes; in fact, the meter generally has no calibration at all. Sometimes the dial divisions are marked off, but not labelled. In a few cases they have been labelled in arbitrary numbers that had no meaning with regard to the amount of current, but just a relative meaning. In other cases there is no pointer, even. The amount of current is indicated by some other method. The user of a

radio receiver incorporating this development I have
44 been describing does not care at all, in the operation of it, how many milliamperes there might be somewhere in the circuit. That is, the significance of the meter as a measuring device is not employed whatsoever, and is of no importance.

In the present-day radio receivers, which include this development of the automatic control with resonance indicator, it is customary to include a manual control, which I described in connection with Figure 1 of my I. R. E. paper, Plaintiffs' Exhibit No. 2. That manual control is included today for use by the listener to adjust the loudness to suit his own preference. This adjustment is performed, not for every signal that is tuned in, nor for every signal that is received. It can be performed once and that adjustment will apply, perhaps, to all the signals you want to receive in one evening. That is, it will be adjusted once and for all, for practical purposes. It is not adjusted at all while you are tuning the receiver.

Referring to Perry U. S. patent 1,536,130 and Friis U. S. patent 1,675,848, just handed to me, which are here in evidence as Defendant's Exhibits B and A, respectively, I am familiar with these two patents. There is no kind of automatic amplification control disclosed in this Perry patent. There is a kind of a visual indicator disclosed in the Perry patent, the meter, marked 20, in Perry's diagram being connected in the plate or output circuit of the detector vacuum tube D. That sort of an arrangement was known at the time I started the development work I have described. It was used in laboratories. In fact, I had used it myself on occasions.

I did not use that type of indicator in connection with my development with automatic amplification con-
45 trol. The function of the meter I used is quite different. I did not connect it the way Perry does because, in the first place, I did not have that kind of a detector in my arrangement, and if I had connected my portable meter in my detector circuit, there would not have been enough current to work the meter. Perry has no device for controlling volume or amplication. At least, no such control is indicated.

In general, this Perry patent describes a point-to-point radio receiver, as distinguished from a radio broadcast receiver. It is the type of receiver that is intended for use for receiving a signal from a particular transmitter, and, more specifically, it is a code receiver, a printing telegraph arrangement for receiving code signals, as distinguished from audible signals or telephone signals. Code signals were audible, but I mean they were not in the nature of speech or music. This Perry arrangement, as described in the patent, could not be used for receiving broadcast signals of the sort we have been talking about, from the various broadcasting stations. The circuit as described is intended for operation in a very different manner. There is no means shown in the Perry patent for selecting one of the large number of broadcast stations. While he has a tuner condenser, as I understand his operation, that is only meant for tuning to one particular station, and the selection accomplished by a single tuned circuit in that manner is far from adequate for broadcast reception.

In the system to which this Perry patent is directed, there is no problem of tuning from one station to another, and eliminating those not desired, as there is in broadcast reception. The problem is very different. There is no
automatic amplification control whatever suggested
46 in the Perry patent. The only visual indicator in
the Perry patent which can be used to indicate relative signal intensities directly, is the meter 20 in the detector circuit. This meter responds to a very small range of signal intensities, perhaps a range in the ratio of three to one, or certainly not more than ten to one, and in a narrow range of signal strength such a meter would give some sort of indication of the relative intensity, but not over a wide range of signal strength. The reading of the meter 20 of Perry is related to the setting of the rheostat marked 21; that is to say, if you change the rheostat 21 between two observations on the meter 20, you would get no indication whatever of relative signal strength by the meter. The similar indication under the tube marked "Detector, D" —that little wiggly line with the arrow head on it—is a conventional symbol for a rheostat connected to the battery, marked A; and, of course, that rheostat would affect the meter current, and if that rheostat were changed, likewise the meter 20 would give no relative indication of signal strength.

In operating a system such as shown by Perry, it is necessary to make adjustments on the rheostat, marked 21, I just referred to. Just how much the unlettered one under the detector, D would have to be adjusted is doubtful, because it is not referred to specifically as far as I have found. Operation of rheostat 21 would affect the reading of the meter 20 so that the meter reading might be consideredably different at different times when receiving the same signal strength, or the meter might be the same when receiving different signal strengths, on account of the adjustment of the rheostat 21.

47 On page 4 of this Perry patent, beginning in line 76, down to line 90, the specification states:

"The operator, while tuning, will throw the switch 22 to substitute a telephone receiver 23 for the receiving relay R. This is done for the reason that the operator will determine whether or not the desired station is signaling by receiving the signals transmitted from the distant intercommunicating stations and these signals will be so weak, because of the reduced amplitude of the frequency emitted by the station which is tuning in, that they will not operate the receiving relay."

My understanding, in this system, as to why Perry says that in tuning he uses the telephone receivers 23 rather than the meter 20, is that, when he is tuning his receiver, the signal is too weak to give a reading on the meter, because the meter in the detector circuit, the way he has it connected, is not sensitive to weak signals, so that he has to tune in using his telephone receivers, and then, after he is all tuned in, he is able to switch over to his recording or printing apparatus, and after he is all tuned in, the meter is likely to give a little indication to aid him in completing the tuning operation. Using the head telephone receivers, as described here, in order to tune a signal required, is tuning by ear.

On page 4, beginning in line 41, Perry refers to the ammeter 20, and he says down there at line 49:

"The maximum ammeter reading will indicate the beat note best transmitted through the band filter and the optimum setting of the variable condenser."

When he says it will indicate the optimum setting of the variable condenser, he refers to the variable condenser in the antenna circuit. That is under the designation "TR". There is a coil indicated and below that a variable condenser with a diagonal arrow through it. That must be the variable condenser to which he is referring, because that is the one that determines the beat frequency transmitted through the band filter. 48 As a matter of fact, there is no other variable condenser shown by Perry.

It is my understanding of Perry's teaching here in this patent, that he does not use the ammeter 20 for tuning. He rather uses the telephone receivers until he is tuned in, and then he finds that meter of some little use in making a final adjustment of his tuning condenser to get just the right final adjustment of the tuning condenser to get the proper beat note to be transmitted through the filter. The beat note is determined by the portion of the Perry system labelled "oscillator detector". The tuning condenser under the general label "TR" is there to control the frequency of the oscillations of the vacuum tube marked "O". It would not be possible to achieve the new results achieved by the system which I have described from this system of Perry.

Turning now to the Friis patent, Defendant's Exhibit A, the arrangement disclosed in the Friis patent was not common knowledge at the time I was working on this development I have been describing. While this Friis patent is a disclosure of some kind of a radio receiving apparatus, there is no disclosure in the Friis patent of any kind of a visual indicator. There is no disclosure in the Friis patent of any problem which would require the use of a visual tuning indicator; there is no suggestion in either the Friis or the Perry patents of any need or requirement for combining any feature of one with any feature of the other.

Even knowing what I now know about my development of the automatic amplification control with a visual indicator, I am not aware of any combination of the disclosures of those two patents which would facilitate the tuning to resonance with incoming signals. 49 In fact, I cannot conceive of any possible combination which could be made which would give the result of the system of mine which I have been discussing.

I have made a study of the disclosure of this Friis patent and may state that the reason why, in the use of a system such as is disclosed by Friis, the operator would require a visual tuning indicator is because of the fact that the arrangement of Friis is an unusual variety of automatic volume control, and it does not behave at all in the same manner as the automatic volume control I have described, that I worked out. One thing you can point to as the main cause of the difference in the operation of Friis from the operation of my arrangement as far as automatic control of amplification is concerned, is the so-called carrier selector in the lower right-hand corner of Figure 1, which comprises the condenser 13 and the coil 14. This selector Friis puts in for a particular reason that he describes, but it has a peculiar effect on the automatic volume control action. The automatic volume control is precluded from operating until the signal is almost precisely tuned in. The automatic volume control does not operate during a great part of the time when a signal would be heard on the loudspeaker, for example. For these reasons the desire for a visual resonance indicator, such as a tuning meter, does not have the same meaning in the Friis application. That is, there is no difficulty in tuning the Friis circuit by ear as accurately as the adjustments permit.

While the behavior of Friis' automatic control would make the tuning difficult, it would not be made any easier
by the presence of a meter. That is what I intended
50 to indicate. This peculiar automatic volume control
circuit of Friis does make the tuning difficult, in the
sense that it has to be done so precisely, but it is not made any easier by the presence of the meter, because you can hear the loudness changing the same as the meter might indicate.

As a practical matter, the sounds from the loudspeaker when tuned with a system like that which Friis shows may be described as follows: let us assume that you are manipulating the main tuning control, which is the oscillator 2, at the top of Figure 1, with the diagonal arrow through it. That arrow indicates that the frequency of that oscillator can be controlled by the user, and I know that in a superheterodyne like the Friis circuit, that tuning control is the main one of the several available tuning controls. Let us assume, therefore, that we want to receive a signal, and that the oscillator tuning control 2 is originally starting several divisions away from the correct tuning point on the dial—that is, so far away that you hear the signal you desire weakly, but not strong enough to be of any use. Then you tune the oscillator in the direction that you find the signal becomes greater, and as you approach the correct tuning point the automatic volume control does not operate, and the sound from the loudspeaker becomes as loud as the full amplification of the receiver can produce. In common terminology, that means that the loudspeaker would blast, with loud and unpleasant and distorted sound as you approach the correct tuning point, and that blasting would continue as you turn the tuning control slowly until you reach the exact, correct tuning point, at which point the automatic volume control would take hold and you would get the normal volume of output from the loudspeaker.

51 If, by mistake, you happened to turn a little beyond the correct point in your manipulation of the tuning control, the blasting would recur on the other side of the correct point. As you tune through the correct tuning point, the blasting comes on both sides of the correct tuning point, and it is only when the receiver is tuned very precisely, to the correct point, that that blasting is avoided and the automatic volume control takes hold. Then, in that sense, tuning by ear is not impracticable with the Friis arrangement. I would say that any user operating the Friis system would be forced, by the loud and unpleasant character of the signal on either side of resonance, to seek the correct tuning point, and he could find it very clearly.

In the Friis circuit there are the following tuning controls: the main oscillator control I mentioned, marked 2, and two variable condensers, one being marked 10 and the other being unmarked, but right opposite the character "4". The character "4" does not apply to that condenser as I read the figure. It applies to a vacuum tube. The figure 10 tunes the radio-frequency loop antenna circuit, while the unmarked condenser opposite the number 4 tunes one of the radio-frequency amplifier circuits. In the operation of a receiver like that shown in the Friis patent, it is necessary to adjust both those condensers every time you want to tune to a different station and the oscillator marked

2 has to be tuned as well each time you change from one station to another.

While I can conceive of the possibility of connecting a meter like that of Perry's meter 20 in the Friis system, the indication that the meter will show as you tune from one station to another, say, by adjusting that loop
52 condenser 10 of Friis, will depend on the state of adjustment of the other tuning controls, especially the oscillator 2. Suppose we assume these conditions: that is, imagine this Friis receiver properly tuned, that is, the antenna or loop tuning condenser set correctly, and the second tuning condenser, by the figure 4, and also the oscillator 2 properly adjusted to receive a given station, and that there is connected in a meter like Perry shows. Now, if these radio-frequency selector circuits are tuned so that they may be resonant to another broadcasting station, the meter would not give any indication on this other station to which the oscillator was not tuned.

By that I mean that it is necessary at least to have the oscillator somewhere nearly tuner. The operation of that circuit, with regard to the behavior of that kind of a meter, is extremely complex. After you are tuned in, it is very simple. The signal gives a little indication on the meter, but it is not of any use in tuning because you are all tuned in. While you are tuning the receiver the behavior of that meter depends entirely on which one of those tuning controls you manipulate first, and, as a practical matter, it would be much simpler to tune the receiver by ear and leave the meter out. The meter is of very negligible utility in tuning the receiver because of its complex behavior that depends on which of those various circuits you tune first. After you had operated the receiver and become thoroughly familiar with it, you might be able to catch on to the tricks involved, but there is nothing simple about it. There is no simple rule. You cannot say that you tune each control for greatest swing on the meter or for minimum current on the meter. There is no simple rule, that is what I mean to say, the meter gives no direct indication of any
53 one setting being correct.

(Adjournment until Friday, March 1, 1935.)

Certified copy of file wrapper and contents was marked "Plaintiffs' Exhibit No. 3" and received in evidence.

Copy of Wheeler application was marked "Plaintiffs' Exhibit No. 4" for identification.

Mr. Guild: I have here the affidavit of Louis Alan Hazeltine. This is the Professor Hazeltine about whom Mr. Wheeler has testified. This affidavit sets forth Professor Hazeltine's experience and points out some facts which have a direct bearing on the questions here before the Court. Mr. Hostetler has just now discussed this affidavit with me and has agreed to stipulate on the record, and does so stipulate, that if Professor Hazeltine were called here to testify he would testify substantially in accordance with what is set forth in his affidavit.

Mr. Hostetler: I agree to that.

The Court: Very well. It may be received.

Mr. Guild: I offer the Hazeltine affidavit in evidence as Plaintiff's Exhibit No. 5.

Affidavit of Louis Alan Hazeltine was marked "Plaintiffs' Exhibit No. 5" and received in evidence.

Mr. Guild: There is another affidavit here, by Milton Merwin Eells. Mr. Eells was formerly employed by the Bureau of Standards of the Department of Commerce, and before that was an executive and in charge of the Communications Division of the National Air Transport Company, the first large commercial air transport company in the country. This affidavit sets forth Mr. Eells' experience with aircraft radio, and points out what he learned
54 about the developments in the Bureau of Standards
when he was there, of their work in blind landing aids for aircraft. That is the development to which I referred in my opening as having included this Wheeler development. Mr. Eells sets forth in this affidavit the facts within his own experience in connection with that work, and in that way it has a direct bearing on the application and utility of the apparatus here involved. This affidavit has also been handed to Mr. Hostetler, who has agreed to stipulate concerning it, and does stipulate, as I understand it, that if Mr. Eells were called here to testify he would testify substantially as set forth in his affidavit.

Mr. Hostetler: I agree to that stipulation.

Affidavit of Milton Merwin Eells was marked "Plaintiffs' Exhibit No. 6" and received in evidence.

Mr. Guild: The third affidavit is one by Vernon E. Whitman, who was mentioned by Mr. Wheeler yesterday in his testimony as having been his roommate at Johns Hopkins University and as having been one of his friends conversant with radio receivers, who had witnessed the demonstration in Mr. Wheeler's home of that radio receiving apparatus which Mr. Wheeler explained included the subject matter here involved. That demonstration, according to Mr. Wheeler's testimony yesterday, took place in the early part of January, 1926. Mr. Whitman's affidavit refers to the fact that he was present at the demonstration and that the subject matter which we have been discussing here was included in it, and that he observed its operation. Mr. Hostetler has agreed to stipulate that if Mr. Whitman were called here to testify he would testify substantially in accordance with what is set forth in his affidavit.

Mr. Hostetler: I agree to that stipulation.

Affidavit of Vernon E. Whitman was marked "Plaintiffs' Exhibit No. 7" and received in evidence.

(The affidavits of Hazeltine, Eells and Whitman, Plaintiffs' Exhibits Nos. 5, 6 and 7, respectively, are set forth *in extenso* at the conclusion of this narrative statement of testimony taken in open court.)

55 Direct examination of Mr. Wheeler Resumed by Mr. Guild:

The Witness: The apparatus which I have developed, as I have testified here, which included the automatic amplification control and with signal intensity indicator, has proven useful in aircraft work in the following respect: In working on the problem of blind landing of aircraft, one of the specific difficulties that the pilot has is determining how far he is at any moment from the airport where he is attempting to land. The meter arrangement I have described indicates the relative signal strength at the receiver, and when a pilot is approaching the airport the relative signal strength is an approximate indication of his distance from the airport, the signals being transmitted, of course, from the airport, so that it has been found possible to calibrate such a visual indicator approximately in terms of miles. This indication is of great value to the pilot in telling him at all times approximately how far he is from the airport. I am not aware of any other direct reading instrument which is feasible to accomplish that purpose.

My invention of the automatic amplification control with visual indicating meter is disclosed in my application Serial No. 203,879, here in evidence. Referring to a copy of the application, just handed to me, in figures 1, 3, 4, 6 and 7, the visual indicator is indicated as a milliammeter marked "MA" on the circuit diagram. Each of these figures is a circuit diagram of a complete receiver, and this meter MA is shown connected where it will function as I have described.

Mr. Guild: Would your Honor like to have Mr. Wheeler point out the parts of that circuit diagram?

56 The Court: I have followed it so far.

Mr. Guild: At first glance they do not look precisely the same as some of the other pictures, although they do correspond exactly, and I thought perhaps it might be helpful.

The Court: Was it one, three, five and six?

The Witness: 1, 3, 4, 6 and 7—all the complete diagrams, in fact.

The Court: Four and six do not seem to be here.

Mr. Adams: I understand from Mr. Hostetler that there is no dispute as to the fact, and that therefore we probably need not take the time to discuss the figures in detail, if that is satisfactory to your Honor, the fact being that the invention that we are here discussing is disclosed in those figures.

The Witness: Four and six are at the bottom of the page.

The Court: You mean at the bottom of page 3?

The Witness: Yes, that is right. It is marked in the middle of the page.

The Court: Go ahead. I think I follow you, perhaps.

Mr. Guild: Suppose Mr. Wheeler refer just to figure 1 briefly, and point out what the important points of it are?

The Court: Very well.

57 The Witness: I will point out the more important parts of the circuit diagram relating to the discus-

sion we have had here. The automatic volume control is accomplished by a connection from the detector tube marked 33, which is the fourth vacuum tube from the left, to the amplifier tube marked 9, which is the first on the left.

The Court: I see that.

The Witness: The milliammeter then is connected in the plate circuit of the amplifier tube 9, and indicates the plate current and, therefore, the relative amount of amplification of that particular vacuum tube. That vacuum tube is one of the three left-hand tubes which are included in the radio-frequency amplifier. The circuits directly associated with the three vacuum tubes on the left, marked 9, 15 and 23, figure 1, corresponding to the box of my chart, Plaintiffs' Exhibit No. 1, labelled "Radio-frequency amplifier", constitute the radio-frequency amplifier. I am referring now to the lower drawing on Plaintiffs' Exhibit No. 1. The vacuum tube 33, and the circuits immediately connected thereto, figure 1, correspond to the detector of the chart. The circuits connected with the vacuum tubes 39 and 47, at the right-hand side, correspond to the audio-frequency amplifier portion of the chart. The loudspeaker is marked 50 on the right-hand side of figure 1 of my application, and is connected to the output circuit of the audio-frequency amplifier. In Plaintiffs' Exhibit No. 1 it is on the right-hand side of the lower diagram. The automatic volume or amplification control connection in figure 1 of my application is the lowest wire shown on the diagram and
58 marked 36. In Plaintiffs' Exhibit No. 1, it is the wire indicated by the line with an arrow on it, and marked "Automatic Volume Control".

The Court: 36 seems to pass upward here at this point.

The Witness: That is where it comes from the detector, your Honor.

The Court: Does that pass on around here to the loudspeaker?

The Witness: No. It jumps those wires. I can follow that path.

The Court: I misunderstood you. I thought you said that wire was the one which led to the loudspeaker. I misunderstood the question.

The Witness: The automatic volume control connection which I have indicated as 36 on figure 1 of my application drawing comes from the detector circuit, from the point labelled "Feed point" through the resistor marked "53", and then back underneath the diagram, through the coil at the left marked "7", to the vacuum tube amplifier 9.

I mentioned yesterday that more recent embodiments of my arrangement of automatic amplification control with a visual indicating device had employed other forms of indicating devices. I had in mind particularly two forms which differed from the ordinary meter, but are, in effect, merely another kind of a meter. One of these forms is sometimes called a shadow meter, and in that form the operator sees the shadow on a translucent screen of a vane which rotates in the place of the pointer on the meter. In other words, the user sees the shadow, which varies 59 in width, and he interprets the width of that shadow as a relative indication of a meter. The other form I have in mind is a Neon tuning light, which is made to look very much like a thermometer. The Neon light occupies only a vertical line in the center of an evacuated bulb, and the length of the illuminated part of the tube varies with the amount of current through the Neon lamp. In other words, the user sees a vertical line which is lighted by the current, and the length of the vertical line is the indication of the amount of current. None of these forms of indicating meters is employed in radio receivers without automatic amplification control.

Referring now to a copy of the Affel patent 1,574,780, just handed to me, this patent is addressed to the broad subject of automatic control of an amplifier; it is not related or directed to radio receivers. It states that it is intended to operate on alternating currents, but that is not a very definite statement, because there are as many kinds of alternating currents as there are currents. By that I mean that this patent might be useful in connection with alternating currents, without being useful at all in radio.

Combining the system shown in this Affel patent with that of the Perry patent which I have been discussing, would result in no advantage over the operation of the Perry patent itself, and the operation would be entirely different, because of the different nature of the circuits. There is no selection of signals or tuning suggested in this

Affel patent nor any suggestion of any sort of indication of signals, either oral or visual.

60 Referring now to a copy of Heising patent No. 1,823,360, just handed to me, I have studied this Heising patent and its expressed purpose is to provide a signal strength recorder especially applicable for recording the slow fading of signals from time to time. By "recorder" I mean making a permanent record of the signal strength, in the same way that you record the temperature and other characteristics in the weather bureau reports. The system disclosed in the Heising patent is of no utility as a visual indication of tuning. The Heising control circuit is a very complicated arrangement of relays and motors and moving parts in general. The mechanical inertia of these parts would make the operation of the control so sluggish that it would be practically useless in tuning the receiver. I note that a loudspeaker 11 is shown, by which tuning could be accomplished much more easily than by any other means in that circuit. It is a laboratory set-up, and its utility would be limited to experimental work, or laboratory work, in making a continual record. It would be of no practical utility in a radio broadcast receiver. For two reasons. One reason is that the amount of apparatus and the cost of the apparatus, and the probability of trouble in the apparatus, because of its complexity, would make it impractical for use in broadcast receivers. The other reason is that in a broadcast receiver we desire a control which is quick in its action, and the Heising control does not meet this requirement. For example, the Heising control would not prevent blasting as you tuned from one station to another. My system requires only a small fraction of a second to operate, while the Heising system would require several seconds.

61 Ordinarily, in operating a receiver of the type having my development in it, it takes about a second to tune the dial from one station to another, and then, having turned it that far, you are constantly moving the dial. It is necessary, for practical operation, that the control circuit operate more rapidly than one would normally tune the receiver, and that necessity or requirement is not met by Heising.

I will identify the parts of this Heising system which are parts in addition to those required in my system. Looking at the circuit diagram in the Heising patent, the diagram is easily regarded in two sections, the upper section and the lower section, that have only a half dozen connecting wires between them. The lower section of the diagram is all additional apparatus, and it is apparatus which is so complicated that a skilled operator would have to be available to keep it in running condition. That includes an expensive relay, marked 12, 13 and 14. It includes a very expensive recording meter 29. It includes two reversing relays 19 and 20, which are adjacent to the two vacuum tubes in the lower part of the diagram, and it requires a motor. The vacuum tubes 15 and 16 on the diagram are also part of the added apparatus. This apparatus also includes a motor 21, which drives a special wire wound attenuator, marked 8. There are also a number of extra batteries indicated in the control circuit; four batteries shown, and in addition there would have to be a power supply for the motor connected to the terminals marked 22. All this equipment I have just referred to is in addition to anything needed in my system.

Referring now to page one of the specification, beginning at line 14 of the Heising patent, I will explain the
62 meaning of the following statement:

"Since the amplitude of a detected signal varies as the square of the amplitude of the received wave, a recorder constructed in the usual manner would be operative over only a small range, as the upper values would be off the scale or the lower values would be unreadable, according to the scale selected."

That refers to the arrangement which is somewhat similar to the detector and meter circuit I described with reference to the Perry U. S. patent. That means that any such indicator, if employed to best advantage, would, at best, indicate the relative signal strength over only a small range of signal intensities, and that the detector and meter circuit of such an arrangement would be entirely unable to indicate relative signal intensities over a wide range, the reason for this being the inherent limitations of the detector and the meter circuit. This statement of Heising, on page 1 of his specification, is a way of stating what I explained yesterday in connection with these prior uses of a meter in the detector plate circuit, such as Perry shows.

Cross-examination of Mr. Wheeler by Mr. Hostetler:

The Witness: Referring to the Heising patent 1,823,360, in the lower left-hand corner, the numeral 29 indicates an indicator. The general purpose of the mechanism shown in the lower part of the drawing is to automatically control the volume of the signals. The upper half of that drawing is illustrative of a radio receiving set.

Referring now to the Affel patent 1,574,780, I think the mechanism of the device illustrated by Affel could be used in a system where waves of radio frequency are received and then transmitted.

63 I have referred to experiments or suggestions of an indicator using shadows. The Philco Company is one company that has used that arrangement very widely. They are one of our licensees.

I have referred to investigations with Neon light as an indicator. While I think that indicators of that type are shown in patents and publications, I do not have a definite recollection of any specific showing.

In the Proceedings of the Institute of Radio Engineers that I referred to yesterday, at the conclusion of the article I referred to the British patent 259,664, Western Electric Company, July 14, 1925. While I am not sure about the claims, the remainder of the patent is substantially identical to the Friis patent. Referring to a photostat of the British patent, just handed to me, the date of application of that patent is July 14, 1925, and it was accepted as complete on October 14, 1926.

Mr. Guild: Those dates are printed on the patent. I do not think this witness has any independent knowledge of that.

Mr. Hostetler: I offer that for purposes of identification as Defendant's Exhibit J.

British patent 259,664, Western Electric Company, was marked "Defendant's Exhibit J", for identification.

Mr. Guild: If your Honor please, as long as Mr. Hostetler has mentioned those two dates, I also want to put on the record that this patent was sealed on January 12, 1927, which is the official date of publication of the British patent.

64 The Court: Do you agree to that?
Mr. Hostetler: Yes, your Honor.

The Witness: In experimental aircraft receivers, at least, they use automatic volume control combined with tuning or resonance indicators. I am not familiar with the commercial receivers.

I would estimate about 10 percent of the home broadcast receivers today use the automatic volume control combined with resonance indicators. I estimate that on the basis that this feature is used almost universally in the more expensive receivers, but because of the additional cost is not used in the extremely cheap receivers which have been recently sold in great quantities. In my estimate of ten percent I have reference to either ten percent of the models or ten percent of the instruments sold and in use, but that is only a rough estimate. It might be, I think, between five and twenty percent.

I know of no use of automatic volume control prior to my demonstration at Chevy Chase, to which I referred yesterday.

Mr. Guild: I would like to have that question and answer more definite on the record, as to whether Mr. Wheeler is talking about other uses or about his own work.

The Witness: I referred to the date early in January, 1926, January 2nd or January 3rd.

The Witness: Referring to figure 1 of my drawing in Plaintiffs' Exhibit No. 4, the part at the left, identified by the numeral 8, having an arrow is a tuning condenser. The elements 17, in connection with radio tube 15, 22, with reference to radio tube 23, and 32, in connection with the next radio tube, are other tuning condensers. In operation, it is necessary to tune each of those condensers in some manner. 65

At the time this drawing was prepared I had in mind the type of receiver which was widely used about 1926. In that type of receiver the left-hand tuning condenser 8 was generally connected with one knob and one dial, and the other three tuning condensers, 17, 22 and 32, would have been connected to be tuned simultaneously and alike, by another knob and another dial. That is, it required, you might say, two hands to tune the receiver, even though there were four tuning condensers. It is the universal practice now, where there are a number of radio tubes, to have all these tuning condensers mounted on a single shaft.

I referred, in my testimony yesterday, to the Howard Radio development. The model that I referred to, that I designed in 1927, was not made in large quantities. I have consulted with the men who were engaged in that work, and they tell me that this receiver was so high priced that they only made about half a dozen in the factory.

Referring, now, to the Perry patent 1,536,130, the numeral at the right, 20, identified by a circle with an arrow in it, is a meter. The purpose of that meter is to measure the current. At the left is a tuning condenser indicated by the arrow. Tuning that was done with that tuning condenser would sometimes be shown by a fluctuation of the meter 20 at the right.

66 Redirect examination of Mr. Wheeler by Mr. Guild:

The Witness: When adjusting the condenser in Perry's patent, I just said that sometimes there would be an indication by the meter 20. By that I mean that, after tuning the receiver according to the instructions of the specification, by means of telephone receivers 23, and listening to those receivers, then you would get a sufficient indication on the meter so that you could use the meter to perhaps improve the tuning a little bit after the set was practically in tune. You could not use the meter to do the major part of the tuning operation at all.

I do not think that receivers having a single tuning control were common yet in 1926, although they were then in the course of development, at least, and appeared very shortly thereafter. However, the advantages which I have set forth here in my testimony on various occasions are true of a radio receiver of the type disclosed in my application here involved, irrespective of how many separate tuning controls may be required. The reduction of the number of tuning controls is another kind of simplification of control.

When I stated that I knew of no use of automatic volume control prior to January, 1926, I meant that I knew of no use by others. I was working on it during the Christmas holidays at the end of 1925, and I was really thinking about the use of it before that approximate date, that is, before the Christmas holidays of 1925, is what I had in mind.

I mentioned that as a rough estimate around ten percent of broadcast receivers so far sold probably include, or do include, this system of mine of automatic amplification control with tuning resonance indicator. That percentage includes as an actual figure about half a
67 million sets a year, I would estimate.

Referring to that Howard radio receiver about which I just testified in cross examination, I stated that it was a very high priced receiver. The style of cabinet used on that receiver accounted for a major part of the price. It was a very heavily carved, fancy cabinet.

Recross-examination of Mr. Wheeler by Mr. Hostetler:

The Witness: If I were asked whether I claim to be the first inventor of automatic volume control, separate and apart from the indicator, my answer would be that there is a question as to what degree of refinement we mean when we say automatic volume control. There were automatic volume controls of a kind which appear to have been invented prior to my own invention of my improvements. I had no first-hand knowledge of this other work. I am merely taking publications on their face value. I would regard the Heising patent that I testified about as being perfectly operative for the purpose for which he intended it to be used. The Affel patent would operate in a way, certainly, but the disclosure is very vague as to the kind of currents, and how it would operate on various kinds of currents. There is an idea disclosed there.

My patent was involved in the case of Hazeltine Corporation v. Abrams, No. 7 Federal Supplement, page 908. Referring to the drawing in that decision, page 908, just handed to me, it is the same as figure 1 of the application in this suit.

68 **Ralph H. Langley**, being called as a witness on behalf of the Plaintiffs and having been first duly sworn, testified as follows:

Direct examination.

By Mr. Guild:

The Witness: I am a consulting engineer in New York City. I reside in Bronxville, New York; 47 Cassilis Avenue, Bronxville. My experience which would qualify me as a radio engineer is as follows: I was graduated from Columbia University in 1913 with the degree of electrical engineer, and was employed immediately after graduation by John Firth in New York City, who was a contractor on radio apparatus. In 1916 I joined the Marconi Wireless Telegraph Company of America, at Roselle Park, which company was also engaged in the development and manufacture of wireless and radio apparatus. In 1920 I went to the General Electric Company at Schenectady, New York, and joined their radio department, which was just formed at that time, and in 1922 I became engineer in charge of receiver design for the General Electric Company. The work of my section, the receiver section, was the development of broadcast receivers for sale to the public, and all the broadcast receivers which were manufactured and sold by the General Electric Company to the Radio Corporation of America, and by the Radio Corporation of America to the public, were developed in my section during those years. In 1927 I left the General Electric Company and joined the Crosley Radio Corporation in Cincinnati, and was director of engineering for the Crosley Radio Corporation until 1931. During that time I
69 continued the supervision of the development of broadcast receivers, and, additionally all the engineering activities of the Crosley Radio Corporation. In 1931 I entered the consulting practice, and have been in that practice since that time. While I was with the Crosley Radio Corporation, the question of automatic amplification control with tuning indicators became something that the manufacturers of broadcast receivers could seriously consider, and I produced, while I was with the Crosley Radio Corporation, several models having the automatic volume control feature. My present consulting practice comprises radio work almost exclusively.

This experience which I have just outlined was such as to acquaint me with the various problems incident to the design and manufacture of radio broadcast receivers and in my duties as in charge of broadcast receiver development, I naturally had to be familiar with the problems and with all the suggestions that were being proposed for their solution, or for improvements in broadcast receivers in general.

I will state briefly the divisions of the subject matter into which those problems fall, in the design of broadcast receivers. Several major divisions of the problem immediately suggest themselves. The first to come to mind is the question of sensitivity, by which the receiver is capable of reaching out and pulling in the distant stations and making them properly audible. Then there is the question of selectivity, by which the receiver is capable of
70 discriminating between desired and undesired stations, so that you can hear the one you want to. Then there is the problem of loud speaker quality. That, of course, has been carried along parallel with these other problems, and developments, in the effort to give the very best possible reproduction of the music and speech in the studio. Then through all the work on these problems, there has been the very important question of making the control of the complete receiver as simple as possible for the user, so that he had no requirement for any knowledge of the apparatus, but merely had to turn a few simple knobs in order to make the receiver produce the desired result. That problem has been one that has been continuously in the minds of the engineers. There is probably still much to be done, but it is being worked on continuously.

A moment ago I spoke of some experience that I had had, as a practical matter, in the manufacture of radio receivers including a form of automatic volume control. I have had occasion, during the past two years, to make a very detailed study of the art of automatic amplification control, and more generally the art of automatic control in this class of devices, whether amplification control or some other type of automatic control. That work has been going on continuously for about two years.

I have studied the references here cited by the Defendant, and before the Court, and am familiar with the Wheeler application Serial No. 203,879, here involved.

Just prior to July, 1927, I was with the Crosley Radio Corporation in Cincinnati, as director of engineering. I

had about 60 men under me there at that time. The Crosley
Radio Corporation was then certainly one of the
71 largest producers of broadcast receivers. I think, in
the following year, 1928, it was the largest. In
rough numbers, that would mean about half a million
broadcast receivers a year.

In general, practically nothing was known in the radio art by radio engineers prior to July, 1927, especially in regard to automatic amplification control and visual resonance indicators in connection therewith. There had been some suggestions of methods that might possibly be used to automatically control the amount of amplification in a receiving system, but all those suggestions seemed to be pointed particularly at point-to-point communication systems, where there was one transmitter working with one receiver, and in which there would be skilled operators to handle the apparatus. I do not believe that, at that time, anyone in the radio engineering fraternity had seen any way that seemed to have the chance of being successful-applied to broadcast receivers to be sold to and used by the public.

As a matter of commercial production and use in the entire radio field, the production and use of radio broadcast receivers is by far the largest part. It probably accounts for at least 90 per cent of the total dollars business done in the radio industry.

There was not, in the early part of 1927, any automatic amplification control system commercially feasible for broadcast receivers.

There was no knowledge, as of 1926 or 1927, of any type
of visual resonance indicator that was a rough-and-ready
instrument that could be applied to a broadcast receiver
in the same way that a speedometer is applied to an auto-
mobile. There were and had been laboratory meth-
72 ods of indicating resonance whenever that became
necessary, and those are much older than anything
here under discussion. They go back to probably 1912 or
1913, but they were distinctly laboratory methods. They
required expensive and sensitive instruments, and they had
limited fields of usefulness, and the laboratory experi-
menter had to know how to use them in order to get results
with them.

There were known in the radio industry in 1926 and the early part of 1927, methods and apparatus actually built for making field strength measurements. Field strength is the strength of a signal as it leaves the station, signal strength and field strength being synonymous. This apparatus was of a complicated laboratory nature, and involved manipulation by men who knew how to adjust it and what it would do. There was no suggestion at that time for any simple, easy method of measuring signal strength or field strength, and these arrangements that were suitable for the purpose were so elaborate and costly that very few of them had been constructed up to that time. The usual method, or the method that had been proposed and was in use at that time, in the measurement of field strength was to have a small calibrated transmitter whose signal strength output was known for any position of the adjustments, and that was part of the measuring rig. The signal to be measured was brought into a radio receiver that had an indicating instrument in its output circuit, and it was adjusted to produce—that is, the receiving set was adjusted to produce a certain indication on that instrument. Then the local transmitter that generated a signal of known strength was turned on, and that local transmitter
73 was adjusted until it produced the same reading on
the instrument. Then the signal strength of the incoming signal was read on the basis that it was equal to the signal from this calibrated transmitter.

The meter which was observed by the user of this apparatus did not actually indicate the signal strength; it simply indicated when the incoming signal and the locally generated signal were the same.

Prior to the first of 1927, there was no apparatus available by which it was possible to tell, by a glance at any one instrument, the relative signal intensity of received radio signals. While it is conceivable that one might have possibly employed the kind of equipment which I have described in connection with this field strength measuring operation, in a location such as in an airplane, the amount of equipment necessary to do it would have been a great burden in any such undertaking. An airplane pilot, as one of his duties while running an airplane, certainly would not have any opportunity to operate this field strength measuring equipment that I have described as being known before 1927. Each measurement with such an arrangement took several minutes to make, and involved the manipulation of several controls, and obviously the airplane pilot could not be bothered with any such procedure as that.

Since it took a considerable time to find out the field strength of any signal as of any particular moment, in order to find out what was happening to the signal, whether it was increasing or decreasing, it was necessary to take successive readings as rapidly as possible, and, of course, that was one of the difficulties encountered in these field strength measurements, that the signal may have changed up or down between two readings, and you had no
74 knowledge of that at all. That is, there was nothing you could look at and tell by observing it what was happening to the received signal in the way of changes in strength.

As I stated, I am acquainted with the system which I have heard Mr. Wheeler describe here in his testimony in connection with his application here involved. The system of Wheeler's, comprising the automatic amplification control with the visual indicator, has gone into widespread commercial use in broadcase receivers, and also into other uses of a more specialized nature, such as the application in the blind landing of aircraft.

I should say that the commercial use of that Wheeler system was increasing. The manufacturers of instruments suitable for this purpose have done a great deal to produce instruments that would be satisfactory for this purpose, and at the same time not too expensive, so that today, the manufacturer of broadcast receivers figures that, above some certain cost, he can incorporate a good visual resonance indicator, and thus give the public the benefit of this easy method of precise tuning.

It is estimated that there are 21 million radio broadcast receivers now in general use. Automatic volume control with a visual indicator would be a valuable improvement on those receivers, providing it is not there already. While that system is in actual use today on many receivers, it is hard to know exactly how many, because the radio industry is not supplied with complete production statistics the way other industries are, so that I have no way of knowing just how many receivers with this feature have actually been sold, but it is certainly a large number.

75 I first became acquainted with this Wheeler system of automatic amplification control with visual indicator when Mr. Wheeler read a paper before the New York meeting of the Institute of Radio Engineers in November, 1927, and I heard him read that paper at that time. That was the first indication that I had had, as an executive engineer in the industry, that there was any method of producing the type of receiver we are here talking about, that was at all feasible commercially.

The fraternity of radio engineers immediately began talking about the possibilities of building such a receiver, and we began talking to our sales executives, as to whether such a feature would have sales appeal, whether they felt it was something that would be useful to them. I say "we" because at that time I had the privilege of traveling quite a little, and meeting other engineers in the industry, and talking these things over with them, and I also talked this matter over particularly with the engineers of the Hazeltine Corporation at that time.

I happened to talk to the Hazeltine Corporation engineers at that time about this development because we—and I mean the Crosley Radio Corporation—were licensees of the Hazeltine Corporation at that time, and we looked to them for advice and assistance in the development and improvement of our product. The Crosley Radio Corporation at that time was also a licensee of the Radio Corporation, General Electric Company, and Westinghouse.

I have studied a copy of the Friis patent No. 1,675,848, just handed me, which has been under discussion here. The general subject-matter to which it is addressed is a proposed method of controlling the amplification of
76 some of the amplifiers in a receiver, in a point-to-point communication system. There is a form of automatic control disclosed in this Friis patent. The system of automatic amplification control here disclosed has one particular peculiarity which is immediately noticeable by the user of such receiver, and that is the fact that the automatic amplification control only goes into action and has an effect after the receiver has been tuned to the signal. During the tuning operation, or while the receiver is being tuned, the automatic amplification control has no effect whatever. That peculiarity is due to the particular arrangement which Friis chose, and shows here, to take care

of one of the problems in automatic amplification control. Other methods have solved that difficulty in other ways, and they avoided this peculiarity that exists in the Friis system.

I have several other methods in mind, some of which are very simple and not very effective, and others of which are more complicated and more effective. Naturally I think of the method proposed by Mr. Wheeler in the present application, and the arrangement which he shows.

The system as disclosed by Friis has never been commercially employed in radio broadcast receivers, nor, so far as I know, has it ever been employed in any type of receivers, although there may have been applications in particular instances that I do not know about and never learned about.

I have observed the operation of apparatus following the system of this Friis patent. In general, the operator of such apparatus observes, as the tuning controls are turned, that the output from the loud speaker builds up,
and if the signal is strong enough, builds up to very
77 high values, and then blasts, as we say, which means
that it overloads and distorts, and makes a racket
rather than a sound, until the three controls here shown are at the exact position of resonance, or very close to it, and when that position is reached the automatic control takes hold instantly and decreases the amplification and the sound comes down to a normal volume, and, of course, the distortion disappears. Then, as you tune away from that point, back come the blasts and the extremely loud sounds and distortion. As you tune still farther away, of course, those are quieted down.

There is no kind of a meter suggested or shown in this Friis patent nor any kind of a visual indicator. I consider that, without a doubt, from a practical point of view, the inherent operation of this Friis system, as I have just explained, is related to its lack of use by the industry. That is, this limitation that I speak of might not be serious in the case of a receiver built to work with one particular transmitter, which, after it had once been adjusted, would not need to be tuned any more, and it would stay continuously in adjustment, requiring only very slight readjustment from time to time; but in a broadcast receiver, of course, any such strange performance as I have outlined would be worse, perhaps, that having no control at all. It would be quite baffling and intolerable to the listener.

Referring to the Perry patent, No. 1,536,130, just handed me, which is here under discussion, I will describe very briefly the purpose of the system Perry discloses. This patent shows a combined transmitter and receiver for the particular purpose of operating a radio printing telegraph circuit. The diagram includes two frequencies, so called, one for transmitting and one for receiving, and the
78 particular object which Perry had was to arrange
such a system so that the operator at either end could break in if something went wrong. Naturally that is a hard thing to do in a radio communication system, and Perry here suggests how it can be done. The receiver which he shows, which, of course, is also partly a transmitter, does not include any tuning in the sense in which we usually think of tuning, but it does include a condenser to adjust an oscillator, the transmitting oscillator, to a frequency very close to that of the incoming signal—and when I say very close I mean so that the difference between the two, the incoming signal and the local signal, is a beat frequency. When I have used the term "signal" I think that I have used it in two senses, that is, a locally generated signal and a signal coming from a distance, and, of course, in this case that is correct, because this is both a transmitter and a receiver.

Perry says his meter, labeled 20, is to tell him when he has adjusted his local oscillator to the best possible value. The system of Perry is based on sending out unmodulated waves, that is, signals that have no variation at all, such as broadcast signals have; and the only signal that he really gets is due to the beat between the local oscillator and the incoming signal, and he uses the ammeter, 20, to adjust that beat to the best value, that is, the value best suited to the apparatus through which he is sending it.

In the operation of the Perry system, that beat, as I term it, in these head telephone receivers shown in the drawing, might be described as a whistle or a flute note, as a single frequency in the audible range, and, of course, with the system as shown, it can be adjusted to any value
79 in the audible range. It probably would be some-
where in the neighborhood of a thousand cycles.

This Perry receiver, that is, the receiving portion that Perry shows would be very impracticable as a radio broadcast receiver, because it contains this band filter, so called, which would only let one particular musical note come through the receiver out of all those that would be coming in, and, additionally, if the oscillator tube "O" in Perry was allowed to oscillate, that would produce another note which would come through and would be disturbing. So, it is impossible to think of Perry's receiver as suited to the reception of such signals as we use in broadcasting.

In the operation of Perry's receiver, the tube "O", marked "oscillator detector", is employed as an oscillator and, in the normal operation of this Perry receiver, you would always have this whistle present at the output where the telephone receivers are. As long as the distant station was sending, and as long as you were receiving any signals from the distant station, you would have the whistle. The system is deliberately designed so that you do not hear anything but the whistle, no matter whether music is received or not.

I cannot imagine any easy, direct combination of the Friis system with the Perry system, which would be of utility. It is conceivable, however, that by suitably modifying Friis' system and Perry's receiver, you might get automatic amplification control in Perry's receiver, and that would be helpful and useful if the signal from the distant station varied in strength at all. After such a change had been made in Perry, by introducing a control system such as Friis shows, the operation of the Perry system would have to remain the same as to this reception only of a whistle which I have just described, because that is essential to have the Perry system work at all. It is based on it. Assuming, for discussion, that such a combined system is in operation, I will consider the change that would be noticed on Perry's detector plate circuit meter, 20, when the receiver is adjusted by the variable condenser under the letters "TR" in Perry's drawing. We must remember that the Friis automatic amplification control method would have no effect while the receiver was being tuned, so that during the tuning time, which, in Perry, amounts to adjusting to get this whistle note, the meter would behave as it had previously behaved. After the control went into operation, however, if the Friis arrangement had been successfully applied, the meter, 20, would show no indication from then on, as the signal changed in strength, because that change would have been eliminated by the Friis automatic amplification control.

In Wheeler's system the tuning indication on his resonance indicator takes place whichever one of the tuning controls is manipulated. As soon as any one of the circuits is near enough to the resonant position to start building up a voltage on the detector, then the automatic control arrangement of Wheeler goes into action, and the meter needle begins to fall, showing that you are approaching the condition of resonance, and, of course, as you improve the adjustment of each condenser, the needle goes farther and farther down, until finally you cannot get it down any more, and then you know you are in exact resonance. That observation and operation is true as to each tuning control and, as a matter of operation, it is the same in principle whether the tuning controls are separate or tied together on one knob, so to speak. Of course, it is 81 a great deal more convenient when they are all on one knob. It can be done more quickly. The benefit of tuning by the visual indicator is present equally in either case.

Referring now to a copy of the Affel patent, No. 1,574,780, just handed me, this patent relates to a generalized method of amplification control, in the language that we are using here, although he calls it "means and method of modulation", which is a little misleading. This system of Affel's could be applied to radio broadcast receivers without any trouble, but it would produce no worthwhile improvement. It is very limited in its capabilities, and that is for the same reason that we noticed in connection with Perry's detector plate circuit ammeter. This depends on a change in the plate current of a triode rectifier tube, and that change inherently is very small for large changes in the applied signal. The situation is such that there is no change in the current of that detector or rectifier tube, "RT", except over a certain range of variation of the strength of the input signal or current, and for changes outside that range there is no response in the detector, either above or below.

(Noon recess.)

Mr. Guild: Before we proceed, if the Court please, I would like to add one other stipulation to the record. It is stipulated that the authors of Exhibit A in the affidavit of Mr. Eells were Messrs. Diamond and Dunmore, of the Bureau of Standards, as is indicated on that exhibit. It is stipulated that the author of Exhibits B and C in the Eells' affidavit was the same Mr. Diamond, of the Bureau of Standards.

Mr. Hostetler: I agree that the articles were written by the authors stated.

82 The Witness: The Affel patent shows, in a very general way, one way of controlling automatically the amplification of an amplifier. The patent makes no attempt to point out specific applications or specific cases where the method might be used. That is what I meant when I said it was a generalized disclosure. The fact is that the method there shown is a relatively simple one, one that would occur, perhaps, first to those who were working in the art, and it has the limitation that I mentioned this morning, by which its range of action or its ability to control is very restricted, and for that reason it is not applicable in the type of apparatus that we are here considering.

The range of control that can be obtained in the Affel system, as shown and described, depends entirely on how much can be accomplished through what happens in a single vacuum tube. As distinguished from that, the Wheeler method is such that it is not limited by what one vacuum tube can do, but it takes advantage of the action of several vacuum tubes, and thus its range of action can be expanded almost without limit, whereas in the case of Affel there is a definite limitation as to what can be accomplished.

As a practical matter, the range of control which is needed in radio broadcast receivers depends upon the following consideration: between the strongest signals that might be received from a broadcasting station, a nearby broadcasting station, and the weakest ones that the user might care to listen to, the ratio is at least as high as one hundred thousand to one, in the actual strength of the signals in the two cases. That means, of course, that any restricted system such as that shown by Affel is quite incapable of coping with the situation. Affel describes 83 in this patent how it operates, and he shows that he gets a control ratio of about two to one. Obviously that is no use in a case where the ratio is as high as 100,000 to 1. With the Wheeler system, on the other hand, it is possible to increase the amount of control almost without limit, up to the amount that you need to have to take care of the situation in hand.

I will now explain what kind of a system would result if it were proposed to employ Perry's meter in the Friis arrangement: Placing Perry's detector plate circuit meter in Friis would result in this situation, that with the oscillator set somewhere near resonance, but not at resonance, as you tuned either of the other circuits in the Friis arrangement you would get an indication on Perry's meter. When, however, you finally succeeded in getting the oscillator exactly tuned, then the automatic control would come into play, and would send the needle of the instrument back almost to its initial position where it was before you started to tune. Just what would happen in any particular case would depend on the order in which you adjusted the instruments of the Friis receiver, but in no case would the instrument be any real aid in tuning, because the oral indication of tuning is so easy and so sure in the Friis arrangement.

If it were proposed to combine, with what Affel shows, the meter as Perry shows it, the only place in the Affel patent where Perry's meter could be put, I suppose, is in the plate circuit of Affel's rectifier. Affel does not have any detector, as such, in his system. Affel does not show any tuning as such. Therefore you would have to mentally add that, and see what would happeen; and, of course, the result is that the meter would give no result as the
84 main signal channel was tuned in the Affel arrangement.
That is because the control circuit is quite separate from the main channel, and there is no way in which tuning the main channel could affect the control circuit, or an indicating instrument in that control circuit.

The Crosley Radio Corporation did not employ either the Friis or Affel or Perry systems in any of its receivers although they were licensed to do so, because those patents were part of the Radio Corporation group of patents. Those systems were not used, within my own knowledge, for the following reasons: Referring specifically to Friis, it was not applicable to broadcast receivers principally for two reasons. It required additional apparatus which we could not consider from a purely economic standpoint. Secondly, it had this defect that I described this morning, by which it did not have any utility until after the receiver was tuned, and, of course, our principal problem was to get something that would control the amplification while the receiver was being tuned. The Affel scheme, on the other hand, was so terribly limited in what it could accomplish that there was no object in trying to do that in a broadcast receiver.

We did not use anything like the Perry system, or an indicating meter like Perry's for the reason that has been pointed out here, that it would only have any utility over a very narrow part of this 100,000 to 1 variation in signal strength. For all other ranges in that enormous range it would give no indication at all.

Referring to a copy of the Heising patent, 1,823,360, just
handed me, that patent does not disclose a system or
85 method with which I had any personal experience;
I have never personally manipulated an apparatus of
the type here disclosed, but the general system disclosed by Heising is one with which I am familiar. I was familiar with it because of a familiarity with all the various components that are used, and a study of the patent itself, to see how they are put together, and what is accomplished by their use.

In my practical experience I have never employed any system of the general type shown by Heising for measuring signal strengths, in the sense that the graphic signal recorders that I have used have been of a different type from this. This one, as you remember, involves a motor and a rotating potentiometer arrangement.

I may describe certain signal intensity measuring equipment I have employed, other than the Wheeler one: At Schenectady, while I was with the General Electric Company, we had a station about 16 miles out of the city, where a field strength measuring equipment had been arranged. That, however, was not a recording arrangement in itself, but recording means could be added to it, which were of a mechanical nature, and some records of that type were made. This type of apparatus was the sort that would be used in laboratories; it was a very elaborate laboratory rig, quite incapable of application to broadcast receivers.

The Heising system disclosed in this patent has no practical applicability to radio receivers for broadcast purposes. It is obviously much too complicated. It is a laboratory rig exclusively. There is nothing disclosed in the Heising patent which would indicate the tuning, or facilitate the tuning operation of a radio receiver, it works much 86 too slowly to be useful as an aid in tuning; except the loud speaker, marked 11, that would be used for the tuning operation, of course. There is no suggestion in the Heising patent that anything else is to be used in connection with tuning the receiver.

The Heising system certainly would not be a practicable arrangement for use on airplanes for the purpose that we were discussing this morning. It works much too slowly, and it requires manipulation. Planes travel too fast to leave time for adjusting an instrument of this type and waiting for it to operate.

Referring now to a copy of a patent to Hagen, 1,990,072, just handed me, this patent to Hagen points out that when a receiver has automatic amplification control it becomes more difficult to tune. He says in the patent, page 1, line 8 and following:

"While in the case of an ordinary receiver set detuning in reference to the incoming waves manifests itself immediately by a marked reduction of the incoming volume, this condition is not quite so conspicuous and apparent in the case of receiver apparatus having automatic volume control means."

Then he goes on, at line 29, to say:

"According to this invention, proper tuning of such a receiver set, and thus the insurance of perfect quality of reproduction, is promoted by that circuit means are provided whereby the automatic volume control may be transiently or temporarily rendered inoperative."

In other words, Hagen feels—and this is a very recent patent, by the way—that the thing to do is to cut out the automatic control completely while you are tuning. Of course, if that is done, the greatest advantage of the 87 automatic control is lost, that is to say the principal object of the control is to avoid these tremendous blasts of sound while you are tuning the receiver, and if you cut out the control while you are tuning, then the blasts come back again, and are just as annoying as ever.

More specifically, the disadvantage that Hagen points out, which he is attempting to solve or to overcome, is that it is a little harder to tune a set that has automatic amplification control, and he proposes to make it easier by cutting out that control while he is tuning.

Wheeler's system provides something which accomplishes the broad result which Hagen is here after. Wheeler provides this resonance indicator so that the user of the receiver, by watching the resonance indicator, can tell when the receiver is properly tuned to the signal. Wheeler therefore has no requirement to make the automatic control temporarily inoperative, and he can therefore avoid the unpleasant consequences that might arise during tuning. That was Wheeler's principal object when he initially started his work, as I understand it.

Speaking of Wheeler's work, I will summarize, from my own experience, what I have observed to be the particular advantages of Wheeler's system over anything that I knew before: The great advantage is that it is now possible to build a receiver, (and has been possible since Wheeler's teachings became available), which can be easily and quickly tuned to any desired signal without any terrific blasts of sound while the set is being tuned, and after it is tuned the amplification is automatically adjusted to the correct value, and the tuning meter indicates what
88 the strength of the signal is relative to other signals.
Of course, from that last fact flow additional advantages. For example, the tuning meter immediately indicates to the user of a receiver whether the set is in proper operating condition. If the receiver is turned on and something is wrong, the tuning meter shows that up at once, and also we notice the further application of it in aircraft, where the meter is calibrated to read distance in miles.

Copy of Hagen patent, U. S. No. 1,990,072, was marked "Plaintiffs' Exhibit No. 8," and received in evidence.

I may state that I disagree with the statement:

"With the volume control of Friis it is possible to determine when the point of true resonance is reached merely by listening to the output as the sound is substantially constant from the time that the field of the station has been entered sufficiently to create the desired volume until this portion of the field is passed."

That statement is distinctly not true of Friis, because of this fact that we were discussing this morning. The automatic control which would be expected to produce that result does not come into action in Friis until the receiver is tuned almost exactly to the center of the signal, so that the sound output is not constant. It is far from constant.

Still referring to Friis, the variations in currents cannot be readily measured by a visual indicator where they cannot be distinguished by ear; they cannot be readily measured by any type of tuning indicator that could be added to the Friis system, because of this peculiar action of the tuning controls and the automatic amplification control. I do not agree with this statement: 89

"With the disclosure of Perry indicating the use of a visual indicator to more accurately assist in tuning the receiver, it would be obvious that variations in the current could be determined by adding a visual indicator to the volume controlled receiver of Friis."

It is not obvious. It is quite obvious, after a sufficient amount of examination of how the Friis system works, that an ammeter in the detector plate circuit would not give a visual indication.

I disagree with the following statement:

"The operator in manipulating the receiver of an ordinary set, having a meter attached in the manner suggested by Perry, would with one hand control the volume as he tunes the set to the various stations with the other."

Of course the operator would not do that. He would not be bothered to do that. He would tune the receiver first, and then adjust the volume afterwards, and if the strength of the signal happened to lie in that narrow range where the Perry detector plate circuit ammeter could indicate something about it, there would be an indication. But if the strength was above or below that range there would not be any indication.

I think something unobvious flows from employing a meter such as shown in Perry, with the automatic volume control of Friis. It is this peculiar performance of the meter, due to the peculiar way in which the Friis control operates as the various circuits are tuned. Certainly it is by no means the case that you merely put the meter in there and then get an indication. That does not happen.

Wheeler does not merely measure a current which
90 varies as the output varies. The output of Wheeler is presumably held substantially constant. Its variation is arranged to be as small as possible. The current that Wheeler does measure is a current that varies because of the action of his automatic amplification control. That is, the output from Wheeler's receiver, is not measured at all with his meter. This measurement of current in the output of the receiver does occur in the Perry receiver, as shown in Perry's patent; the current in the detector output circuit is measured, but its variation is shown only under certain restricted circumstances.

The particular distinction between what is measured by Perry's meter and what is measured by Wheeler's meter is that Perry's meter measures the output of his receiver, and Wheeler's does not. In a particular instrument it probably would be possible to get a relationship between the output current of the receiver and the reading of Wheeler's meter, but, of course, there is no reason for doing that, and it would have to be especially calibrated. However, the meter is capable of doing that. Assuming that the output in Wheeler's structure here involved, when set to true resonance on stations of different intensities, was exactly the same, there certainly would be a difference in the position of the pointer of the visual indicator. If the output was alike, but the signal intensities were different, the meter would show by its reading for the two stations what that difference was.

I disagree with this statement, still referring to Wheeler's system:

"The variation in the indication is caused by the fact that the volume control, while substantially sufficient as to the sound effect on the ear, is not fully effective in compensating for different current strengths when measured by the visual meter."

91 I would say that that statement indicated a more or less complete misunderstanding of the situation. Ob-

viously Wheeler's automatic volume control is arranged deliberately and intentionally to change the grid voltage on the amplifier tubes, and that changes the current in the plate circuits, and that is the current that is measured. There is no question of the control being capable of regulating the sound output, but not capable of regulating the current. It does regulate the current.

Properly speaking, the variation in the amplification is measured in Wheeler's system and the meter can be calibrated in terms of gain, which is our usual way of speaking of amplification. The variation in amplification is not a variation corresponding to the output which is measured in Wheeler. It is a variation corresponding to the intensity of the incoming signal, and adjusted with respect to that intensity. Indirectly, it is the same variation that actuates the visual indicators in Wheeler's receiver and that of Perry. Of course, one is a reading of the plate current of a controlled amplifier. The other is a reading of the plate current of a detector in a receiver that has no control. But it is not the same variation with respect to the particular current that is actuating the indicator. It is a different current entirely.

Even by properly manipulating the volume with one hand, a conventional set provided with a meter, as suggested by Perry, obviously could not be used for the purpose of measuring the intensities of the input currents, because every time the volume control was moved that would alter the calibration of the instrument, even admitting that the instrument could read over a wide
92 range. So that the only way you could measure signal intensity with such an arrangement would be to have an elaborate calibration of volume control positions and the meaning of the meter indication for each position. By "meaning of the meter indication for each position" I mean some kind of a chart, a curve between volume control position and meter indication and signal strength—a series of such curves.

At the time of Wheeler's development, skilled engineers were not fully familiar with the principles of automatic volume control. I assume that his development was about January, 1926.

Commenting on the statement:

"The plate current of the controlled amplifier tubes would have larger variations, which will permit the use of a more rugged and cheaper indicator."

I may say that they do have larger variations, but that does not permit the use of a more rugged indicator. The fact is that the detector plate circuit ammeter that we have been talking about, and the amplifier plate circuit ammeter, would probably be the same type of instrument, having the same range. The interesting fact is that when the meter is placed in the amplifier plate circuits it sweeps over its whole range, and covers the entire gamut of incoming signal intensities, whereas in the other case it can, at most, swing only over a small part of its range and only for a narrow band of signal intensities.

If asked whether anyone skilled in the art would have failed to understand that the use of a measuring instrument with the amplified current would be more practical, my reply would be that, in the first place, it is not an amplified current. It is a controlled current. It is controlled by the automatic control, and it is a thing 93 which the user of the apparatus cannot see by looking at it. Somebody had to discover that this current was varying as the automatic control operated, and that therefore a meter could be placed in that circuit and would give this indication. Skilled radio engineers at, say, July, 1927, were not fully familiar with the principles of automatic volume control. It was not until the fall of that year that they began to think about it at all. I certainly consider that Wheeler's development was at that time a forward step in the radio art.

In my work in these radio manufacturing companies that I testified to, I was in the habit of hiring and working with many skilled radio engineers. I think at the Crosley Radio Corporation I had a group of about 60 men, as I recall it, varying a little from time to time; and at the General Electric Company probably about 25 or 30 men in my immediate section. I would say that the development which we have been identifying here as Wheeler's automatic amplification control system with visual indicator was not within the expected skill of such radio engineers to develop, even though these radio engineers that I just referred to were men skilled in the art, and some of them produced very creditable novel arrangements and new developments.

Cross-examination of Mr. Langley by Mr. Hostetler:

The Witness: As a radio engineer experimenting in the laboratory, the method I found most convenient for measuring the strength of currents, in general, of course, was with ammeters. That was the only method of measuring the strength of a current as such. The manner in which the ammeter was used for measuring currents of that
94 character depended on the conditions; you selected a suitable ammeter, opened the circuit, and inserted the ammeter in the opening of the circuit.

Turning, now, to the Friis patent, the band filter marked "6" in the upper right-hand corner of figure 1 is a part of the superheterodyne receiving system, and it corresponds to a selective system intended to separate a desired signal from other undesired signals. I agree with the statement, on page 2 of the specification, of the Friis patent, line 13:

"The function of filter, 6, is to separate out and transmit only the intermediate frequency waves corresponding to the difference between the incoming wave frequencies and the auxiliary wave frequencies."

Any waves that pass through the band filter would be impressed upon the loudspeaker 9. These waves also would be impressed upon the circuit 13 and 14, at the end of the connection extending downwardly from the receiver part. Even if this band filter filters out the undesirable waves, there could still be blasting on the loudspeaker 9, due to the fact that the signal applied to the system is much too strong for the amplifying tubes, and much louder in its ultimate output than the user cares to hear. The same signal would be impressed upon the circuit 13 and 14. Whenever there was fading in the speaker 9, that impulse or that corresponding fading feature would be present in 13 and 14, if the receiver was accurately tuned, which, of course, it would be by the time you became interested in the fading of a particular signal.

Mr. Hostetler: In the automatic control arrangement as shown by Wheeler, and also by Friis, is there any variation in signal strength at the detector?

The Court: At the detector?

95 Mr. Hostetler: At the detector.

Mr. Adams: May I interrupt there? I do not know whether Mr. Hostetler intended to convey the idea that the two automatic control systems are the same.

Mr. Hostetler: No.

Mr. Adams: Your question indicated that to me.

The Witness: Answering, first, as to Wheeler, there is a slight variation in the signal intensity as applied to the detector grid. The nature of the control system is such that some variation must be allowed to remain in order that the control system may operate. With respect to Friis, the same holds true after the receiver has been accurately tuned to resonance, but only then.

Affidavit of Louis Alan Hazeltine

(Plaintiffs' Exhibit No. 5.)

State of New York,
County of New York, ss:

Louis Alan Hazeltine, being first duly sworn, deposes and says:

I am an electrical and radio engineer by training and profession and at the present time am engaged in consulting practice, in addition to my duties as Professor of Physical Mathematics at Stevens Institute of Technology, Hoboken, New Jersey.

I was graduated from Stevens Institute of Technology in 1906 with the degree of Mechanical Engineer. After a year's practical training with the General Electric 96 Company at Schenectady, I joined the Electrical Engineering Department at Stevens and was head of that department with the title of Professor of Electrical Engineering from 1918 to 1925. I began specializing in radio in 1915 and during the war served as consulting engineer in radio in Washington Navy Yard, where I made the engineering design for a radio receiver (SE 1420) that went into wide use in the Navy. Later I served on three of the four Radio Conferences called by the then Secretary of Commerce Herbert Hoover to assist in solving the problems arising from the advent and rapid expansion of radio broadcasting.

I have personally carried on various researches in the development of broadcast radio receivers and have cooperated in other such researches.

I have taken out many patents in the fields of radio and of the application of vacuum tubes to power purposes; and I was the inventor of the "Neutrodyne" radio receiver, the first highly selective, easily controlled broadcast receiver to come into wide popular use. I have presented various papers and discussions on radio subjects. I have been elected to the highest grades of membership in the following professional and scientific societies: Institute of Radio Engineers, American Institute of Electrical Engineers, American Society of Mechanical Engineers, American Physical Society, American Association for the Advancement of Science. In the Institute of Radio Engineers, I served for several years on the Board of Direction and on the Standardization Committee, being chairman of the subcommittee on vacuum tubes. In 1933, I received the honorary degree of Doctor of Science from Stevens Institute of Technology.

97 I have studied carefully U. S. patent application Serial No. 203,879, filed July 7, 1927, by Harold A. Wheeler, which I am informed, is involved in the action above-entitled. This Wheeler application relates primarily to a simple and practicable circuit arrangement for automatically controlling the amplification in a radio receiver so that the volume of sound developed in the loudspeaker is nearly the same for a weak received signal as for a strong signal. But Wheeler's arrangement for automatic control of amplification has another valuable feature, which is that particularly involved in this action: it makes practicable and convenient the use of a visual indicator, or meter, to show when the receiver is in tune with any signal and to indicate the relative intensity of the signal, without requiring any additional adjustment or manipulation on the part of the user, in spite of the enormous range in the intensities of signals that can be received. This is an accomplishment unknown to the radio art prior to Wheeler's work and one which has proved highly acceptable to the users of radio receivers, as shown by its now general use in high-grade broadcast receivers.

For many years prior to 1927, I was accustomed in the laboratory to use meters in radio circuits, both to indicate

tuning and to measure the intensity of signals; but I never considered them feasible for commercial broadcast receivers, because no way was then known for making them responsive to all signal intensities that were to be received. The force of this consideration comes from the fact that signals are often received at one moment from a station say 5 miles away and at the next moment from a station 500 miles away and that, if the stations are equally powerful, the ratio of power received in the two cases will
98 be over 10,000 to 1, since the power varies more rapidly than the inverse square of the distance. With any arrangement known to the prior art, a meter suited to the strong signal could give no visible response to the weak signal.

Wheeler's automatic amplification control overcame this difficulty by reducing the great range in received signal power to a small range in output. But it did more than this: it made available a meter connection peculiarly appropriate to the conditions, in that Wheeler's meter is relatively more sensitive with weak signals than with strong signals. This novel connection consisted in placing the meter in the plate circuit of a *radio-frequency amplifier tube,* whose characteristic curve has such a form as to give the desirable result just stated. No such connection of a meter was known prior to Wheeler's work; and it would have had no utility in the prior conventional receivers, since a meter so connected in such receivers would have given no response whatever to a signal of any ordinary intensity.

If it had been attempted to employ a tuning meter in a radio receiver prior to Wheeler's work, such a meter would naturally have been connected in the plate circuit of the detector tube (as was done, for example, in the system disclosed in the patent to Perry, No. 1,536,130). For this was the only tube in the conventional broadcast receiver whose plate current, as read on a meter, changed when a signal was received. In order that such a meter should indicate tuning to any of the signals that might be received, it would have been necessary for the user to manually adjust a volume control at the same time that he was adjusting the tuning. This would have made the tuning meter worse than useless; for the manipulation would have been more
99 difficult than tuning by ear. Of course, such a tuning meter would have been entirely ineffective with

respect to the other use of the Wheeler meter, that of indicating relative signal intensity.

I am familiar with U. S. patent No. 1,675,848 to Friis, which discloses a form of automatic amplification control in a radio receiver. There is no disclosure or suggestion of the use of a visual indicator of resonance or of signal intensity. If the Friis arrangement were applied to such a system as that of Perry, having a tuning meter in the plate circuit of the detector tube, the particular advantage of the Wheeler meter connection would, of course, have been absent; and, moreover, the behavior of the meter when the various tuning adjustments were made would have been such as to render it of no practical advantage.

AFFIDAVIT OF MILTON MERWIN EELLS.

(Plaintiffs' Exhibit No. 6.)

STATE OF NEW YORK,
County of New York, ss:

Milton Merwin Eells, being duly sworn, deposes and says:

I am an engineer having the degree of Bachelor of Science from Hamilton College. I reside at 11 High Street, Orange, New Jersey, and am a member of the technical staff of the Breeze Corporations, Inc., of Newark, New Jersey.

I became intimately familiar with aircraft and radio for aircraft in 1918 when I was in France in the Air Service of the American Expeditionary Forces.

100 In the early part of 1929, I became manager of communications for National Air Transport, which was the pioneer American commercial air transport company. As manager of communications, it was my responsibility to see that the company's planes were equipped as rapidly as possible to take every advantage of radio communication. In this connection I became thoroughly familiar with the specialized problems relating to aircraft radio communication and the need for simplifying the operations necessary on the part of the pilot. Because of the weight limitations imposed by the particular planes then in use we found it was economic to limit the airplane radio equipment to beacon receivers for receiving the signals from the airways weather broadcasting stations and

radio range beacons developed and installed by the Bureau of Standards and the Department of Commerce.

This work brought me into close contact with Mr. Harry Diamond of the Bureau of Standards who was then in charge of research and development of radio aids to air navigation. In the fall of 1930, I went to College Park, Maryland, where Mr. Diamond and his group had installed a radio system for blind landing of aircraft. A highly successful flight demonstration was given, and I was much impressed because my experience showed the urgent need for means allowing a pilot to land at an airport under conditions of poor visibility.

Because of my experience in aircraft radio and my particular interest in the problem of blind landing, in December, 1932, I joined this group in the Bureau of Standards under Mr. Diamond. By that time, they had made many improvements in their blind landing system and their pilots had made many successful landings while
101 under a hood which required flying and landing the airplanes entirely by instruments and radio aids.

In order to familiarize myself with the details of the development work that they had done, I studied various publications which dealt with this development. Among these were a paper on "A Radio Beacon and Receiving System for Blind Landing of Aircraft", by Diamond and Dunmore, in the April 1931 Proceedings of the Institute of Radio Engineers, pages 585-626. Photostatic copies of pertinent pages of this paper are attached hereto as Exhibit A (now 6A). I also recall having read the article entitled "A Radio System for Blind Landing of Aircraft" in the August 15, 1930 issue of the "Air Commerce Bulletin", photostatic copies of selected pages of which are attached hereto and marked Exhibit B (now 6B); and an article entitled "Automatic Volume Control for Visual Radio Range Beacons Developed", which was published in the December 1st, 1930 issue of the "Air Commerce Bulletin", of which a photostatic copy is attached hereto and marked Exhibit C (now 6C). I recall these articles in particular because they give a very good description of the blind landing system I worked with.

One of the features of the airplane installation was the incorporation in the beacon receiver of automatic volume control with a milliameter in the plate circuit of the radio-frequency amplifier tubes. The milliameter was calibrated in miles and gave the pilot an approximate indication of his distance from the bacon transmitter. It was also useful in other ways such as serving to indicate when the receiver was correctly tuned, to indicate when in preliminary flights the pilot had passed over the transmitter and was actually going away from it and to act as an instantaneous check to the mechanic on the ground and to the pilot in flight that the receiver was in operating condition.

102 This arrangement is correctly described at page 600 of Exhibit A (now 6A) in the following words:

"The provision of this automatic volume control device made possible the addition of an important instrument on the airplane instrument board, giving the pilot information as to his approximate distance from the localizing beacon transmitter. Since increasing input voltage to the receiving set is accompanied by increasing negative biasing voltage on the grids of the radio-frequency amplifying tubes, the deflection of a direct-current milliameter connected in the plate circuit of these tubes will decrease as the airplane approaches the beacon transmitter. This meter (see Fig. 10) may therefore be calibrated directly in approximate distance from the transmitter. Its calibration will hold roughly on different localizing beacons at different airports, provided these beacons are of approximately the same power ratings. Its chief function is, however, to give the pilot an added check that he is approaching or departing from the landing field and should aid materially in avoiding confusion during blind flight."

The same feature is also referred to in Exhibit B (now 6B) at pages 83-84; and in Exhibit C (now 6C) at pages 274-275.

Affidavit of Vernon E. Whitman (Plaintiffs' Exhibit No. 7).

STATE OF NEW YORK,
County of Queens, ss:

Vernon E. Whitman, being duly sworn, deposes and says:

I am a radio engineer by profession. I have been employed in that capacity by the Hazeltine Corporation since June, 1929. I reside at Flushing, New York.

I have received from the Massachusetts Institute of Technology in 1922 the degree of B. S. in Electrochemical Engineering and in 1924 the degree of M. S. in Physics. Subsequently, I have received from Johns Hopkins University in 1926 the degree of M. A. in Physics and in 1928 the degree of Ph. D in Physics.

103 I was formerly associated with the United States Bureau of Standards, Washington, D. C., in the capacity of physicist. I served in the Capacitance and Inductance Section and in the Electrical Instrument Section of the Electrical Division, and also in the Aeronautic Instrument Section. I was engaged in research and development work requiring both theoretical and practical knowledge of physics and electrical engineering.

Since 1913, I have been actively interested in the construction and operation of radio receivers. I have constructed a number of amateur and broadcast receivers.

Since about 1924, I have been acquainted with Mr. Harold A. Wheeler. We were both living in Washington, D. C., at that time. During the winter of 1925-1926, we shared the same room in the dormitory at Johns Hopkins University where we were both enrolled in the Physics Department. At that time, Mr. Wheeler was retained by the Hazeltine Corporation and was actively engaged in studying problems connected with radio receivers. He frequently discussed with me the work he was doing. I recall in particular that he showed me in his notebook various circuits relating to automatic volume control. This feature was not then to be found in commercial broadcast receivers but is now used almost universally in such receivers. The novelty of automatic volume control as described to me by Mr. Wheeler naturally attracted my interest. Mr. Wheeler and I spent the Christmas holidays at the end of 1925 at our respective homes in Washington. On the evening of January 3, 1926, Mr. Wheeler entertained some of his friends, including myself, at his home. Those of us who were especially interested in radio were invited to witness a demonstration of an experimental receiver which Mr.
104 Wheeler had been working on. This receiver embodied automatic volume control and he successfully demonstrated to us the operation of this feature. I was so much impressed by this demonstration that I have retained a clear recollection of it.

The automatic volume control caused the loudness of the signal to be maintained nearly the same during reception of signals which had a wide range of intensity. Mr. Wheeler tuned the receiver to Station KDKA, of Pittsburgh, which was noted for the fading of its signals. He pointed out and I observed that the fading was not apparent during the operation of the automatic volume control but became apparent when he changed the connections to render the automatic control inoperative. He tuned the receiver successively to both distant and local stations. I noticed that there was very little difference in loudness and that the signals were received clearly.

During the demonstration of this receiver, Mr. Wheeler particularly called our attention to a Weston Model 280 meter which he had connected in an operative relation with the automatic volume control circuit, so as to be actuated by the received signal. This was unusual because it was not customary to include in broadcast receivers any meter actuated by the signal. He demonstrated to us two useful functions which were performed by this meter. One of these functions was the indication of signal variations during fading and the other was the indication of resonance as an aid in tuning the receiver.

While Mr. Wheeler was demonstrating his receiver on the reception of KDKA, he pointed out that the meter deflection was fluctuating noticeably while there was no apparent fluctuation of loudness. He explained that
105 the meter fluctuation depended on the signal
strength and therefore fluctuated with fading.

When Mr. Wheeler tuned from station to station, he pointed out that the meter reached an extreme deflection when each station was tuned in. Such a meter would have been very useful in commercial receivers as an aid in tuning to the signals.

The so-called tuning meters which are now used on many of the commercial broadcast receivers operate substantially in accordance with my recollections of Mr. Wheeler's demonstration. I have found these meters very useful in the operation of such receivers both as an aid in tuning and as an indication of relative signal strength. In all such receivers with which I am familiar, this meter is actuated by the automatic volume control circuit of the receiver.

It is hereby stipulated by and between counsel for the respective parties to the above-entitled cause, subject to the approval of the Court, that the foregoing Statement of Evidence is true, complete and properly prepared, that it contains the substance of all the evidence given on the hearing of this cause, and that it may be considered as a record of the trial of said cause in making up the transcript of the record on appeal.

And it is further stipulated that either party may refer to the original transcript of the testimony taken at the trial and to the original documentary exhibits offered
106 in evidence therein for correction of errors in the printed record.

CLARENCE M. FISHER,
Solicitor for Plaintiffs.
R. F. WHITEHEAD,
Solicitor for Defendant.

Dated, July 26, 1935, Washington, D. C.

Upon reading and considering the foregoing stipulation, it is, on motion of counsel for Plaintiffs herein—

Ordered, by the Court that the foregoing condensed Statement of Evidence be duly approved as true, complete and properly prepared and as containing the substance of all the evidence given on the hearing of this cause, and be made of record this 1st day of August, 1935.

F. DICKINSON LETTS,
Justice, Supreme Court of the District of Columbia.

107 In the Supreme Court of the District of Columbia.

In Equity.

No. 55,874.

HAZELTINE CORPORATION and HAROLD A. WHEELER,
Plaintiffs,

vs.

CONWAY P. COE, Commissioner of Patents, Defendant.

Exhibits to Accompany Statement of Evidence.

Plaintiffs' Exhibits:

1. Diagrammatic Chart.
2. Proceedings of Institute of Radio Engineers, January 1928, Vol. 16, No. 1, pp. 30-34, inc.

3. Certified copy of file wrapper and contents of application of Harold A. Wheeler Serial No. 203,879, filed July 7, 1927.

4. Copy of Wheeler application and claims as now before the Court.

5. (Affidavit of Louis Alan Hazeltine—included in Statement of Evidence.)

6. (Affidavit of Milton Merwin Eells—included in Statement of Evidence.)

6A. Proceedings of Institute of Radio Engineers, April 1931, pp. 585, 599, 600, 601 and 603. (Exhibit A in the Eells Affidavit—Plaintiffs' Exhibit No. 6.)

6B. Air Commerce Bulletin, August 15, 1930, pp. 79, 83 and 84. (Exhibit B in the Eells Affidavit—Plaintiffs' Exhibit No. 6.)

6C. Air Commerce Bulletin, December 1, 1930, pp. 271-275, inc. (Exhibit C in the Eells Affidavit—Plaintiffs' Exhibit No. 6.)

7. (Affidavit of Vernon E. Whitman—included in Statement of Evidence.)

8. U. S. Patent No. 1,990,072 to Hagen.

108 *Defendant's Exhibits:*

A. U. S. Patent No. 1,675,848 to Friis.

B. U. S. Patent No. 1,536,130 to Perry.

C. (Prints of Wheeler application drawings—in Plaintiffs' Exhibit No. 3).

D. (Examiner's Statement in Wheeler application—in Plaintiffs' Exhibit No. 3).

E. (Decision of Board of Appeals in Wheeler application—in Plaintiffs' Exhibit No. 3).

F. Decision of Examiner of Interferences on Motion to Dissolve and to Amend, Interference No. 60,839, Simonds v. Wheeler.

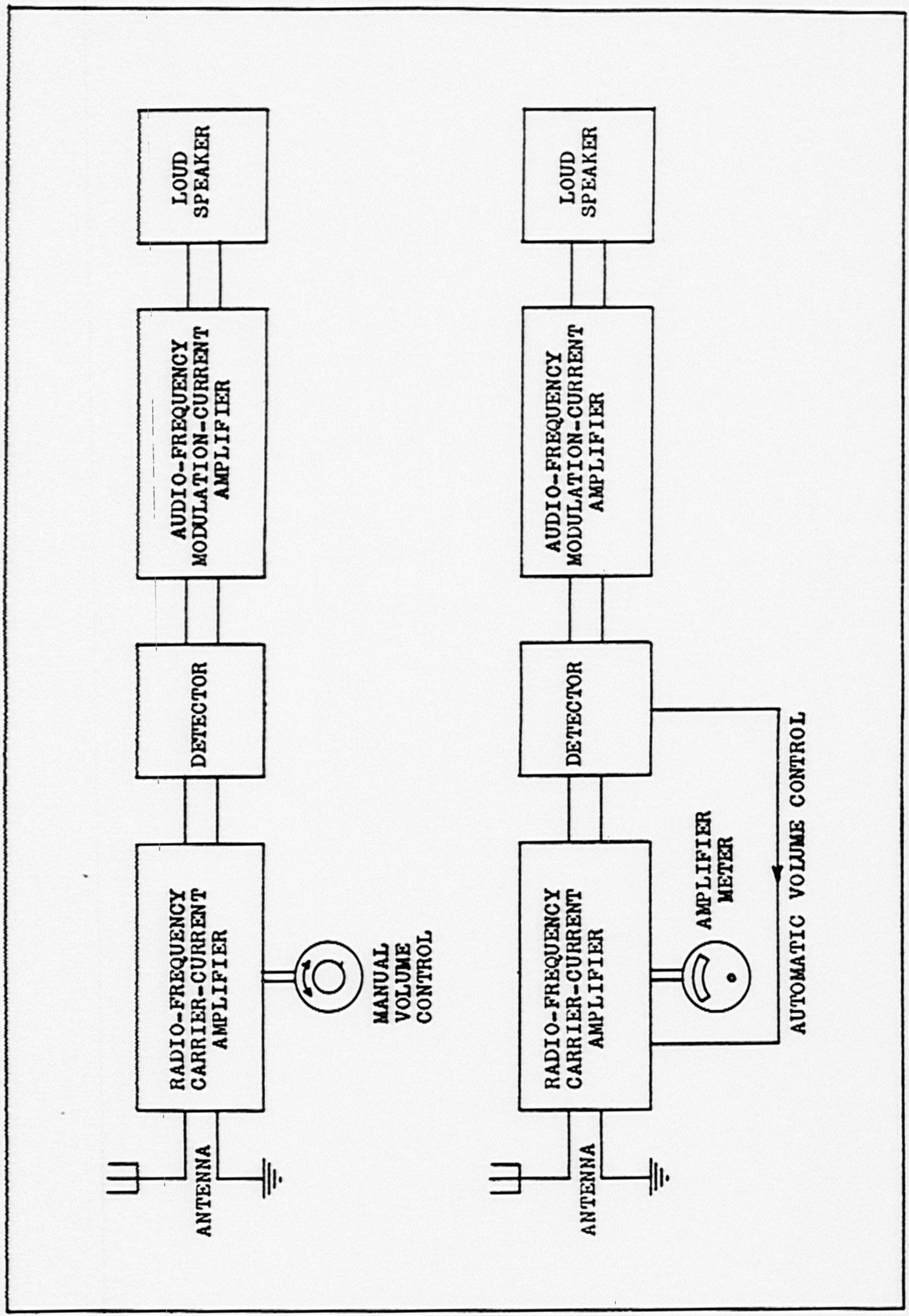
G. Decision of Board of Appeals in Interference No. 60,839, Simonds v. Wheeler.

H. U. S. Patent No. 1,823,360 to Heising.

I. U. S. Patent No. 1,574,780 to Affel.

J. British Patent No. 259,664 to Western Electric Co., Ltd.

Plaintiffs' Exhibit 1.


ANTENNA
RADIO-FREQUENCY CARRIER-CURRENT AMPLIFIER
DETECTOR
AUDIO-FREQUENCY MODULATION-CURRENT AMPLIFIER
LOUD SPEAKER
MANUAL VOLUME CONTROL
ANTENNA
RADIO-FREQUENCY CARRIER-CURRENT AMPLIFIER
DETECTOR
AUDIO-FREQUENCY MODULATION-CURRENT AMPLIFIER
LOUD SPEAKER
AMPLIFIER METER
AUTOMATIC VOLUME CONTROL

Plaintiffs' Exhibit 2.

AUTOMATIC VOLUME CONTROL FOR RADIO RECEIVING SETS*

By
Harold A. Wheeler
(Hazeltine Corporation)

Summary—*A receiving set is described in which the radio-frequency amplification is automatically controlled to give a nearly constant radio-frequency voltage at the detector, independent of differences in antenna signal voltage. This results in nearly uniform response at the loud-speaker from nearby and distant broadcasting stations and also reduces the effect of fading. The method employed consists in using the rectified carrier voltage to adjust the grid bias of the radio-frequency amplifier tubes. There are indicated the solutions of special problems that arise in carrying out this method.*

In the present radio receiving sets employing high amplification, it is necessary to adjust carefully a "volume control" in order to reproduce signals of different intensities with the same audible intensity from the loud speaker. There are various devices which could be employed to regulate automatically the amplification of the signal, some of which employ moving mechanical parts. It is the purpose of this paper to describe a simple electric circuit, without moving parts, in which the amplification is regulated automatically by the signal, and the loud speaker intensity reaches approximately the desired level for each signal, independent of the signal intensity and therefore irrespective of a reasonable amount of fading.

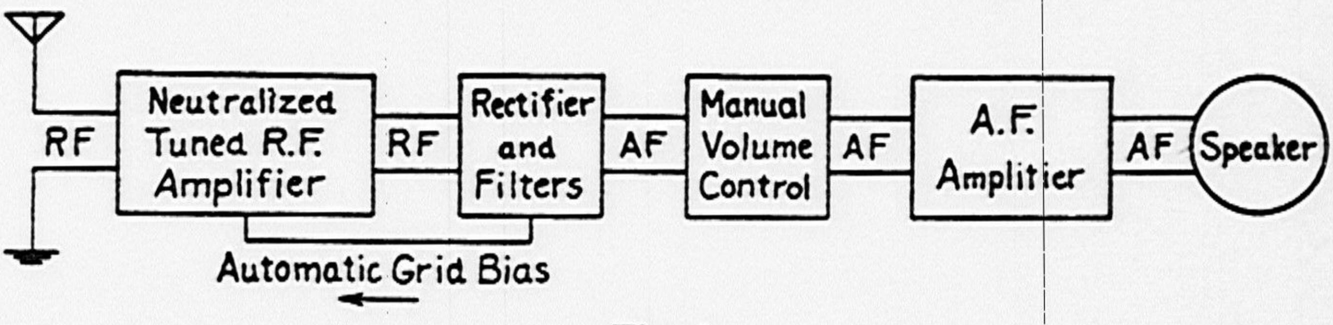


Fig. 1

Any device to accomplish this object without introducing distortion of music or speech must operate by the signal carrier wave. Any variations in its intensity must be compensated by reciprocal variations in its amplification. The method to be described provides for controlling the radio-frequency amplifier, thereby maintaining the desired signal level in the detector or rectifier, audio-frequency amplifier and loud-speaker.

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* Received by the Institute, October 6, 1927.

* Presented before the Institute of Radio Engineers, New York City, November 2, 1927.

Fig. 1 shows the outline of a set which has been constructed for broadcast reception, embodying this automatic volume control, comprising the following component sections. (1) A four-stage radio-frequency amplifier of the well-known Neutrodyne type, with UX 201-A tubes, the antenna circuit tuned by one dial and the four coupling transformers tuned simultaneously by a second dial. The total amplification is controlled by varying the negative grid potential of the first three tubes. (2) A two-element rectifier with simple filter circuits to reject the radio-frequency currents and to segregate the direct and audio-frequency components of the pulsating rectified voltage. (3) A manual volume control in the form of a voltage attenuator connected to the grid of the first audio-frequency amplifier tube. (4) A four-stage audio-frequency amplifier and loud speaker. The entire set, excepting the last two audio-frequency stages, was enclosed in a grounded metal box divided into compartments, one for each tube with its preceding coupling circuit.

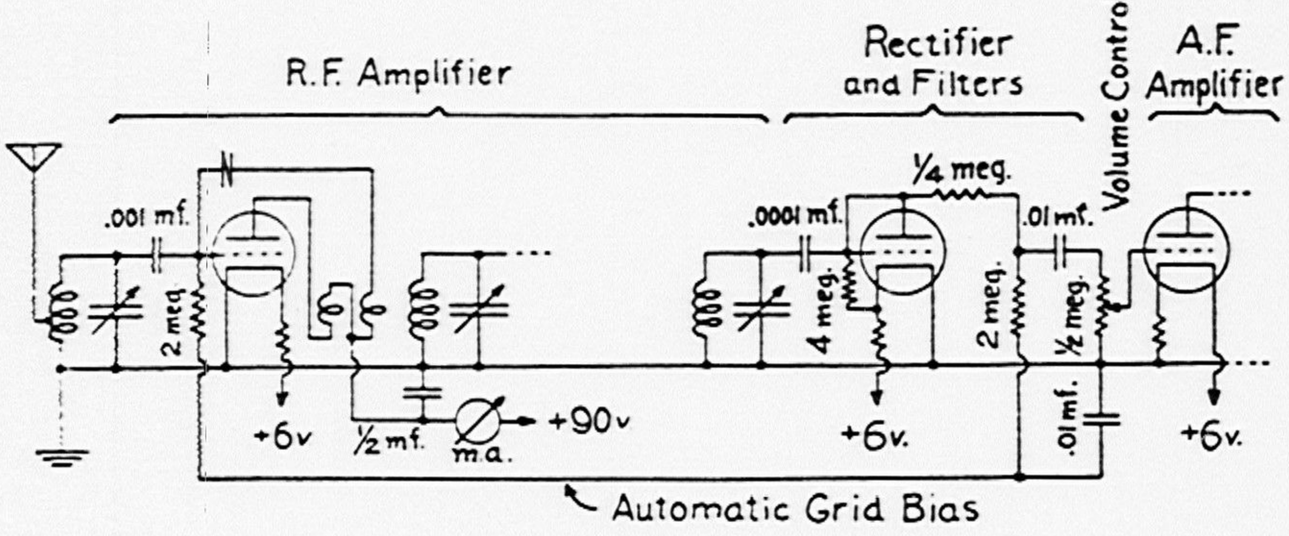


Fig. 2

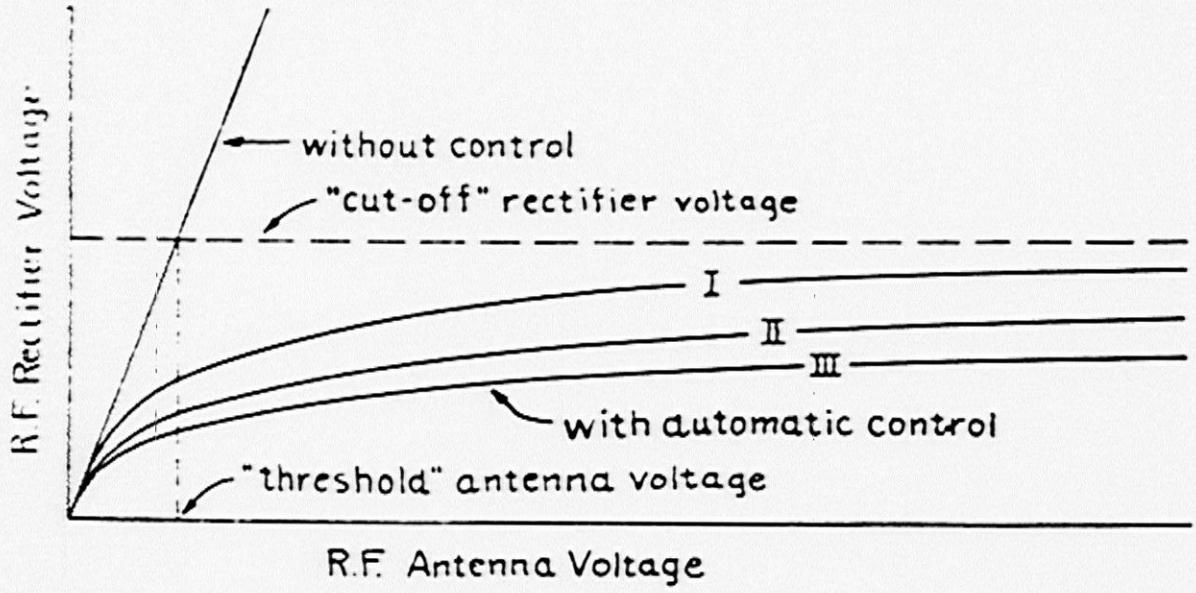


Fig. 3

Fig. 2 shows the essential circuit details pertaining to the control system. The direct component of the rectified voltage, free of audio-frequency variations, is applied to the grids of the first three tubes. If the radio-frequency rectifier voltage could exceed a value of about ten volts, this automatic grid bias would thereby cut off the signal through the radio-frequency amplifier, so the rectifier voltage cannot exceed this value.

Fig. 3 shows graphically the comparison between the performance of the radio-frequency amplifier with and without the automatic control. With the system described, the rectifier voltage and audio-frequency voltages are nearly independent of the antenna voltage, when the latter exceeds the threshold value. The curves I, II, and III show the performance of the system when the automatic grid bias is applied to one, two, or three tubes, respectively, of the radio-frequency amplifier.

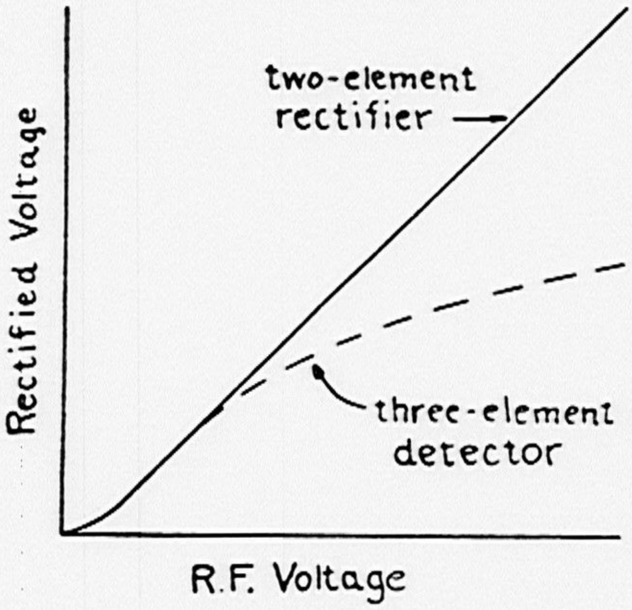


Fig. 4

The degree to which the signal can be cut off in one tube is limited by two factors. First, any error in neutralizing the grid-plate capacity permits signal current to pass through the tube, even when its mutual conductance is zero. Secondly, the sharp bend in the plate-current grid-voltage curve causes distortion of a strong signal on the grid, when the mutual conductance is reduced too far by the grid bias. In view of such limitations, it is undesirable to reduce the amplification ratio per stage below about 1/10 of its normal value. When controlling several tubes, these limitations become unimportant. The last radio-frequency stage is not controlled because it must supply as high as ten volts to the rectifier.

The properties of the two-element rectifier contribute largely to the simplicity of the control system. Fig. 4 shows the nearly linear proportionality between alternating and rectified voltages in this form of rectifier, as contrasted with the irregular performance of the three-element detector. The signal modulation is rectified without distortion. Also the average rectified voltage is equal to the rectified carrier voltage, while with a "voltage-squared" detector the average rectified voltage is proportional to the average total power of carrier and sidebands. This last feature is worthy of mention in connection with the control system, since the automatic grid bias should depend only on the carrier amplitude, independent of the modulation.

With the circuit constants shown in Fig. 2, the time constant of the circuit which connects the rectifier to the grids of the control tubes is 1/40 second, so that the control system comes nearly to equilibrium in 1/20 second. This time can be reduced further if necessary, but is ultimately limited by the allowable reduction of the signal modulation at the lowest audio frequencies.

In consequence of the automatic control action, it becomes difficult to tune the receiving set accurately by ear to a desired signal. The amplification of the controlled tubes is decreased as the response to the signal is increased by tuning, and vice versa, so that the point of resonance is indicated by minimum plate current in the radio-frequency amplifier. Taking advantage of this fact, a milliammeter (*m.a.*, Fig. 2) is connected in the plate circuit of the first tube, to be used as a resonance indicator, and also to give an indication of relative signal intensities.

There is an incidental problem in supplying the plate current to all tubes of the set described from a common rectifier and filter system. In the controlled radio-frequency amplifier tubes, when operating at low plate current, the signal carrier is modulated appreciably by small fluctuations in the plate voltage. Such fluctuations are caused by the plate current pulsations in the audio-frequency amplifier. In the presence of a strong carrier wave, these two effects may cooperate to generate a low frequency oscillation. This disturbance may be avoided by reducing the internal output impedance of the rectifier-filter, by decreasing the amplification at low frequencies in the audio-frequency amplifier, or by using separate rectifier-filter systems to supply the plate currents of the radio- and audio-frequency amplifiers, respectively.

The performance of the automatic volume control as described can be summarized briefly as follows. A maximum variation of signal voltage in the ratio of 1:1000, corresponding to differences in distance, fading, or tuning, results in a maximum variation of the rectified carrier voltage in the ratio of only about 1:3. This small variation, together with possible differences in the degree of modulation of different stations, can readily be compensated if necessary by adjusting the manual volume control for the audio-frequency amplifier, which also determines the "volume level" for the automatic volume control.

The name "Audiostat" has been selected for this device, by reason of its tendency to maintain the audible intensity at a constant value.

Attention might be called to British Patent 259,664 (Western Electric Co., July 14, 1925), in which a somewhat similar system is presented. This latter system is applied to a super-heterodyne receiving set, and is more involved in several respects than the system described in this paper.

It is desired to acknowledge the cooperation of the Howard Radio Company of Chicago, in whose laboratory the set described was assembled.

Claims 50, 51, 66 and 67 do not materially differ from the claims passed upon by the Board of Appeals in the above noted decision.

C. D. BACKUS,
Examiner, Div. 51.

Pennie, Davis, Marvin & Edmonds, 165 Broadway, New York, N. Y.

290 [Stamp:] U. S. Patent Office. Board of Appeals. Feb. 1, 1933. Mailed.

Appeal No. 7262. Paper No. 26. Decision.

REH.

Appeal No. 7262.

Hearing: January 19, 1933.

In the United States Patent Office.

Before the Board of Appeals.

Ex parte Harold A. Wheeler. Application for Patent. Filed July 7, 1927. Serial No. 203,879. Amplifier Volume Control.

Messrs. Pennie, Davis, Marvin & Edmonds for applicant.

The claims considered in this appeal are 68, 69 and 72-77 inclusive.

The matter involved is the same as that considered by this Board in Interference 60,839 and our decision there should be consulted for a complete statement. From line 3 of page 2 to, and including, line 2 of page 6 of that decision, rendered February 20, 1932, is to be regarded as a part of this decision.

Appellant, however, has presented some additional argument and we therefore add the following statement to our *inter partes* decision in view of the new argument.

In the brief it is stated in effect that what appellant discovered that others had not appreciated 291 was that, if the receiver is tuned to exact resonance it will have the greatest reserve for automatic volume control. It must be remembered that patents in this art are addressed to skilled engineers and we cannot believe that such engineers, fully familiar with the principles of automatic volume control, would not have understood this fact.

Another reason now particularly urged as to the exercise of invention relates to the subject matter of the more specific claims in which the current of one of the amplifier tubes is specified and appellant points out that these currents have larger variations which will permit the use of a more rugged and cheaper indicator. We cannot conceive that anyone skilled in this art would fail to understand the- the use of a measuring instrument with the amplified current would be more practical.

Other arguments presented in this appeal we consider are sufficiently covered in the other decision. We might add, however, that obviously we cannot substitute for our own judgment the opinions of others, even though those testifying may be recognized as of outstanding ability. We are still of the opinion, as set forth in our original decision, that the employment of a measuring instrument for determining when a receiver is in resonance did not require the services of an inventor and for the reasons above stated we regard the particular location of the instrument as an obvious one to a radio expert.

In view of the communication received from
292-299 appellant January 23, 1933, the appeal is dismissed as to all claims except those listed in the opening paragraph. The decision of the examiner is affirmed as to the remaining claims and it is held that claims 72-77 inclusive, which are claims originally considered by us in the *inter partes* decision, are unpatentable. It is recommended that these claims be restored to the case for purposes of appeal.

F. M. HOPKINS,
Assistant Commissioner,
W. L. THURBER,
Examiner-in-Chief,
E. T. MORGAN,
Examiner-in-Chief,
Board of Appeals.

February 1, 1933.

300 *Plaintiffs' Exhibit* 4.

In the Supreme Court of the District of Columbia.

Hazeltine Corporation and Harold A. Wheeler,
Plaintiffs,

vs.

Conway P. Coe, Commissioner of Patents, Defendant.

Application of Harold A. Wheeler. Serial No. 203,879.
Filed July 7, 1927. For Amplifier Volume Control.

Specification, Claims, and Drawings in Suit.

301 This invention relates to amplifiers, and more particularly to amplifiers utilized in modulated carrier-current signaling systems wherein the limit of amplification is automatically maintained substantially at a predetermined level.

When amplifiers are employed for amplifying a signal voltage it becomes desirable for various reasons to control automatically the amplitude of this amplified signal voltage. To this end the present invention provides means for effecting automatic amplification control. Such an arrangement, for example, is particularly advantageous in radio receivers such as are employed for receiving broadcast signals, because it prevents the overloading of the last amplifier stage of the receiver, which overloading would result in distortion of the reproduced signal, as well as loud and harsh reproduction.

Another advantage resides in uniform reproduction of the amplified signal irrespective of whether the carrier-current signal is received from a nearby station or from a distant station, or a high-power station, or a low-power station, since it has been found in former radio receivers that when the receiver was reproducing strong signals as from a nearby, or a high-power station, the audibly reproduced signal was very loud, whereas when the signal was received from a distant, or a low-power station, it was relatively weak, with the result that if signals were to be reproduced uniformly from both near and distant stations, and from high-power and low-power stations, it became necessary to readjust some volume controlling means in the receiver to compensate for these unequal signals.

302 It has also been a common experience in the use of former radio receivers that the reproduced signal was not uniform due to the phenomenon of "fading", whereby the received signal occasionally, or periodically, became much weaker, or faded almost to the point of inaudibility. Since the present invention provides an amplifier which automatically compensates for inequalities in the received carrier-current signal strength, when "fading" takes place the degree of amplification is correspondingly increased and the reproduced signal maintained at its former volume, so that a listener is unaware that variation of the received carrier-current signal is occurring. This automatic compensation for signal fading is especially advantageous in commercial radio telephony and like systems.

In present radio receivers in which operating current is derived from the municipal power system, it has been found that when there is considerable variation in the line voltage supply, the volume of the reproduced signal is not uniform. An additional advantage of the present invention is that of automatically compensating for such line voltage variations with the result that the reproduced signal is uniform in volume.

A still further advantage is the saving in plate current which is automatically effected during the reception of powerful signals, for the reason that this invention incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases.

Fig. 1 is a circuit diagram of a complete radio receiver which includes the present invention, and consists of
303 a three-stage radio-frequency amplifier followed by a rectifier, a two-stage audio-frequency amplifier, and a loud speaker, or other suitable indicating device.

Fig. 2 shows curves disclosing the relation between the radio-frequency antenna voltage and the radio-frequency amplified voltage, with and without the application of the present invention.

Fig. 3 shows a circuit diagram of a second embodiment of the invention in which there is disclosed a three-stage tuned radio-frequency amplifier, a rectifier, and a three-stage audio-frequency amplifier.

Fig. 4 represents the present invention embodied in a radio receiver including a two-stage radio-frequency amplifier, a detector, and a two-stage audio-frequency amplifier.

Fig. 5 shows a modified form of coupling arrangement and controlling network which may be substituted for the corresponding elements inclosed in the dotted rectangle of Fig. 4.

Fig. 6 shows a diagrammatic arrangement of a radio receiver incorporating the present invention, and operated entirely from a rectified and filtered alternating source of current, thus eliminating the "A", "B" and "C" batteries now so widely used.

Fig. 7 is a circuit diagram of a radio receiver in which several of the features of the present invention are combined in a single embodiment.

Fig. 8 shows graphically a comparison between the performance of the two-electrode valve or rectifier, and of the three-electrode detector.

304 Referring in detail to Fig. 1, there is shown an antenna 5 connected to ground 1 thru the primary winding 6 of a radio-frequency transformer, the secondary winding 7 of which, tuned by a variable condenser 8, is connected at one point to the filament of the vacuum tube 9 in the first radio-frequency amplifying stage and at another point to the grid 11 of this vacuum tube. The output circuit of this vacuum tube extends from the filament system, thru a high-voltage battery "B", a milliammeter 10, primary winding 13 of a second radio-frequency transformer to the anode or plate 14 of this vacuum tube. In order to neutralize the inherent capacity between the grid 11 and the plate 14, and thereby to prevent oscillations, and otherwise to increase the effectiveness of the present invention as hereinafter described, a neutralizing winding 19, electromagnetically coupled to winding 13, and a neutralizing condenser 3 are employed in the manner described in the U. S. patents to Hazeltine Nos. 1,489,228 and 1,533,858.

A second stage of radio-frequency amplification including the vacuum tube 15 neutralized by cooperation of coil 26 and condenser 4, like the first stage, comprises the secondary winding 16 of the last-mentioned radio-frequency

transformer tuned by a variable condenser 17 connected between the filament system of the vacuum tube 15 and the grid 18 thereof. The output circuit of this vacuum tube also includes the high-voltage battery "B" and a primary winding 20 of a second radio-frequency transformer, while the secondary winding 21 of this transformer tuned by a variable condenser 22 is included in the input circuit of a
third stage of radio-frequency amplification which
305 includes vacuum tube 23. The inherent capacity
effective between the electrodes 24 and 25 is neutralized by a network including the neutralizing condenser 28 and the neutralizing winding 29 as described in the mentioned patents. The output circuit of the vacuum tube 23 includes the primary winding 30 of a third radio-frequency transformer and the high-voltage battery "B". The secondary winding 31 of this last-mentioned transformer, tuned by a variable condenser 32, is connected in the input circuit of a rectifier 33 which input circuit includes the fixed condenser 2. The rectifier employed may be of the type commonly known in the art as a two-electrode "Fleming" valve, or may consist of an equivalent such as a three-electrode vacuum tube, as shown, having its grid 12 and its plate or anode 35 directly connected together to comprise in effect a single anode.

It may here be noted that thruout the present specification and claims the terms "rectifier" and "detector" are, in general, used interchangeably, the terms "rectifying" and "converting" being employed in the general sense to include the process of changing alternating current into a form of direct current or modulated unidirectional current. Likewise, the terms "carrier-current" and "modulation-current" may be substituted, respectively, for "radio-frequency current" and "audio-frequency current", since the description herein of radio-frequency amplifiers and audio-frequency amplifiers is merely by way of example of a typical embodiment of the present invention.

In the absence of the present invention including
306 the control circuit 36, to be described, the three-stage
amplifier functions in a manner well-known in the art to amplify the incoming signal intercepted on the antenna 5. The output circuit of the rectifier 33 includes what may be termed a "rejector" circuit for stopping radio-frequency currents which have passed thru the rec-

tifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 38 of the rectifier. The output circuit of the rectifier is coupled to the input circuit of an audio-frequency amplifying vacuum tube 39 thru an audio-frequency-pass filter including a fixed condenser 40 and an impedance 41 connected between the filament 42 and the grid 43 of this vacuum tube. The output circuit of this amplifier is connected between the filament 42 and plate 44 thru the high-voltage battery "B" and the primary winding 45 of an audio-frequency transformer the secondary winding 46 of which is connected in the input circuit of a second audio-frequency tube 47, while a resistance 48 connected across the winding 46 serves to give the audio amplifier substantially uniform amplification over the desired frequency range. Instead of employing resistance 48, a closed copper band of suitable size may be placed around the transformer winding so as to be electromagnetically coupled thereto. A loud speaker or other reproducing device 50, or if required, a coupling device for a telephone system, is connected in the output circuit of the last audio-frequency amplifying tube 47. It is presumed that adequate precautions against undesired electro-magnetic coupling between the various radio-frequency coupling transformers are included in all of the arrangements herein disclosed.

307 In accordance with the main features of the present invention, means are provided to control automatically the degree of amplification effected in the radio-frequency amplifying stages. These means include a resistance 51, connected between the filament 38 and the anode 35 of the rectifier, thru which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal 52. This negative voltage is applied over conductor 36 thru the impedance 53 and the secondary winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency stage. Impedance 53, together with blocking condenser 54, is effective to filter out and reject any audio-frequency currents which otherwise might be present in the conductor 36.

To complete the description of the system illustrated in Fig. 1 certain design data or constants are given herewith. It should be understood, however, that these, as well as all other constants appearing in the present specification, are mentioned merely by way of example in describing certain specific embodiments which in practice have proved eminently satisfactory, and are not intended to suggest any specific limitations as to the scope of this invention. Accordingly, fixed condenser 2 may be of 0.0005 microfarads; 37 of 0.0001 microfarads; 54 of 0.01 microfarads; 40 of 0.005 microfarads; resistance 51 of 1 megohm; 34 of 1 megohm; and 41 and 53 of 2 megohms each.

308 In the operation of the receiver shown in Fig. 1, a signal intercepted on the antenna 5 is successively amplified thru the neutralized radio-frequency stages indicated by the vacuum tubes 9, 15 and 23. This amplified signal voltage is then rectified by the rectifier 33, and the rectified pulsating current is successively amplified by the audio amplifying stages including vacuum tubes 39 and 47, after which it may be reproduced as sound by the loud speaker 50. When the rectified or converted signal current flowing thru the resistance 51 is greater than a predetermined value, there is developed at the terminal 52 sufficient negative biasing voltage which in turn is impressed, thru the conductor 36, upon the grid 11 of the vacuum tube 9, to reduce the amplification of this tube. It will be apparent that as the magnitude of the rectified current flowing thru resistance 51 decreases with weaker signals, the voltage at terminal 52 becomes less negative, and the negative biasing voltage impressed upon the grid 11 also diminishes so that the vacuum tube 9 effects an increased degree of amplification. In this manner, the radio-frequency voltage applied to the input of the rectifier is maintained at a nearly constant predetermined value, and the volume of the reproduced signal is substantially uniform under all conditions. The degree of volume of the reproduced signal is then determined by adjustment of rheostat 49 which controls the heating current in the filament 42 of the first audio-frequency amplifying tube 39. The neutralization of the grid-plate capacity of the radio-frequency amplifying tubes is, in combination with the present invention, particularly valuable in that it allows an increase in the effective-
309 ness of the amplification control, because such neutralization prevents radio-frequency energy from passing thru the grid-plate capacity of the tubes. Thus the relay action of the tubes is almost entirely subject to the

control by grid bias voltage provided in accordance with this invention.

The time required for operation of the control system would ordinarily be determined by the lowest audio-frequency modulation which must be reproduced. Fading, for example, might be considered a form of modulation; the frequency of the rise and fall of signals due to fading being the frequency of modulation. If this frequency of modulation be increased sufficiently, the effect will be audio-frequency modulation. It will thus be seen that if the automatic control attained by the present invention be allowed to respond too quickly, it will tend to smooth out the desired modulation of the signals at the lower audio frequencies. Hence, a time constant of operation is chosen which will be greater than the period of the audio frequencies which the system is intended to amplify. This time constant of the control circuit is equal to the product of the series resistance and the shunt capacitance of the grid bias circuit, represented in Fig. 1 by resistance 53 and capacitance 54. However, since the time constant can always be reduced to a value equal to the period of the lowest modulation frequency, it may readily be set to meet the requirements of nearly any special case which may arise. For example, a value of two million ohms resistance and of 0.1 microfarad capacitance gives a time constant of one-fifth of a second, which does not appreciably
310 affect the modulation of frequencies above five
cycles. While this constant is greater than required from the point of view of satisfactory audio-frequency quality in the reproduction of music, there appears to be no need for more rapid control under the conditions usually encountered. The use in this connection of condensers of large capacitance, such as one-tenth microfarad, likewise introduces another convenience in that the condensers may also serve to by-pass radio frequencies in order to prevent undesired coupling between the detector circuit and the first radio-frequency amplifying tube because of some impedances common to those two portions of the apparatus.

For a better understanding of the present invention reference is made to Fig. 2 from which it will be appreciated that in a system similar to that illustrated in Fig. 1, but in which no means for automatically limiting the degree of amplification is included, the amplified radio-frequency voltage is proportional to the radio-frequency antenna voltage, as indicated by curve 102. When, however, the present invention is employed in such an amplifier, the relation between the radio-frequency antenna voltage and the amplified radio-frequency voltage is indicated by curve 103 from which it will be seen that when at least a certain predetermined radio-frequency antenna voltage is present, (herein referred to as the "threshold antenna voltage") the amplified radio-frequency voltage approaches—but is always less than—another certain predetermined voltage value (herein referred to as the "cutoff voltage").

311 The modification illustrated in Fig. 3 is an especially desirable form of the present invention, and includes antenna 56, connected by means of a transformer 57 to a neutralized three-stage tuned radio-frequency cascade amplifier including the vacuum tubes 58, 60 and 62 coupled by transformers 59 and 61. The last stage of the amplifier is connected by a transformer 63 to a two-electrode rectifier 64 of the type already described, the output circuit of which, including the resistance 65, is connected between the anode 66 and filament 67 of the rectifier, as previously explained. Resistance 72 and condenser 68 associated with this output circuit, constitute a "rejector" network which filters out the radio-frequency current component in the output circuit of the rectifier 64, while the network including condenser 69 and resistance 70 constitutes an audio-frequency-pass filter for coupling the output circuit of the rectifier to the input circuit of the audio-frequency amplifier which includes vacuum tube 71. Rheostat 73 controls the heating current supplied to the filament 74 of this vacuum tube, and thereby permits a manual adjustment of the volume of the reproduced signal desired by the listener. Audio-frequency transformer 76, which is preferably of a low ratio of transformation, couples the output circuit of vacuum tube 71 to a second audio-frequency amplifying tube 77. This last vacuum tube in turn is coupled by a second audio-frequency transformer 78 to a third audio-frequency amplifying tube 79 in the output circuit of which there is included a loud speaker 80.

312 In this arrangement automatic amplification control is effected in a manner slightly different from that shown in the diagram of Fig. 1, since in this instance the radio-frequency voltage of the signals intercepted by

the antenna 56 is successively amplified by three neutralized tuned radio-frequency amplifying stages including the vacuum tubes 58, 60 and 62, of which two are controlled in accordaance with the present invention. The amplified radio-frequency current is rectified by the rectifying valve 64, and successively amplified at audio-frequency by the vacuum tubes 71, 77 and 79. The rectified current in the output circuit of the rectifier flows thru the resistance 65, and thereby develops a negative voltage at the terminal 81, which voltage is applied thru the impedances 72, 82, 83 and 85 to the grids 84 and 86 of the radio-frequency amplifying tubes 58 and 60. By thus simultaneously controlling the degree of amplification of two successive radio-frequency amplifying stages a greatly increased uniformity of regulation is attained. Impedance 82 and the condenser 87 constitute an audio-frequency-stop filter, so that substantially only direct-voltage is impressed upon the grids 84 and 86. It will be understood that the voltage developed at terminal 81 is a function of the amplified radio-frequency voltage delivered to the input circuit of the rectifier by the radio-frequency amplifying tubes 58, 60 and 62, and therefore, as the negative voltage at terminal 81 tends to increase with the increased signal, the resulting increase of biasing voltage impressed upon the grids of the tubes 58 and 60 limits the degree of amplification effected in the radio-frequency stages including those tubes.

313 In this arrangement the constants for the various resistances and condensers may, for example, be the same as those for the corresponding elements in Fig. 1. In addition the grid resistances 83 and 85 may have a value of 2 megohms each; and the grid condensers connected at the junction of these resistances and the grid electrodes 84 and 86 may each be of 0.001 microfarad capacity.

The modification shown in Fig. 4 differs from the arrangement of Figs. 1 and 3 mainly in that it employs a three-electrode vacuum tube which functions in the manner of the well-known three-electrode detector, and also effects rectification, or conversion, of the radio-frequency carrier current to control amplification in the first radio-frequency stage of the receiver. As in the preceding arrangements, there is here employed an antenna or other suitable signal interceptor 88, coupled by means of a radio-

frequency transformer 89 to a two-stage neutralized tuned radio-frequency amplifier including the vacuum tubes 90 and 91 coupled by means of a radio-frequency transformer 92. The output circuit of the last stage of the amplifier is connected by means of radio-frequency transformer 93 to the tuned input circuit of a three-electrode vacuum tube detector 94, which input circuit is tuned by the inductance of the secondary winding of transformer 93 in shunt to variable condenser 95. A suitable negative voltage is maintained on the grid 96 of the detector tube, through the secondary winding of transformer 93, by "C" battery 97 and by potentiometer 98 connected across the filament of the detector tube. By means of this
314 potentiometer connection, a negative voltage may be applied to the grid 96 varying from one volt to a maximum of five volts; the minimum value being the difference between the six volts of "C" battery 97 and the voltage drop across the filament of the detector. The output circuit of the detector includes the primary winding of transformer 99, a 45-volt battery 100 and a $500,000 ohm resistor 101, connected in series between the anode of the detector and the common "B" battery. A fixed condensor 104 by-passes the radio-frequency current that has passed thru the detector, while the audio-frequency component of the rectified, or converted, current is transferred thru the audio-frequency transformer 99 to the input circuit of an audio-frequency amplifying vacuum tube 105 the filament circuit of which includes rheostat 106 for controlling the arbitrary volume level of the amplified signals. The output circuit of the audio-frequency amplifier 105 is coupled by means of an audio-frequency transformer 107 to the input circuit of a second audio-frequency amplifying tube 108. The output circuit of this vacuum tube includes the usual loud speaker or indicating device 109. A resistance 110 is connected across the secondary winding of transformer 107 to secure substantially constant amplification within the frequency range of the audio-frequency amplifier, especially when the plate resistance of the preceding tube 105 is high as a result of the adjustment of rheostat 106.

For controlling the amplitude of the radio-frequency voltage applied to the input circuit of detector 94, a con-

ductor 111 is connected at point 112 common to a terminal of resistor 101 and battery 100, and thence through
315 the secondary winding of transformer 89 to the grid of the first radio-frequency amplifying tube 90. A by-pass condenser 113 connecting the conductor 111 to the filament system serves to filter out and reject any audio-frequency currents present in the circuit including the conductor 111, thereby insuring that these currents have no effect on the grid of the vacuum tube 90. Battery 100 is the source of negative biasing voltage applied to the control-grid, or control-electrode, of the radio-frequency amplifying tube, this battery being so connected to the output circuit of the detector, or rectifier, that fluctuations of voltage in the detector output circuit cause equal fluctuations in the negative biasing voltage impressed upon the control-grid.

In this embodiment, condensers 104 and 113 may be of 0.0005 microfarad and 1 microfarad capacity, respectively; while resistance 101 may have a value of 0.5 megohm.

In adjusting the receiver of Fig. 4, it is necessary to determine the correct setting of the detector grid potentiometer 98. This adjustment should be made while there is no signal being received, as follows: First, the switch 115 is closed, and the normal plate current of the tube 90 is noted on milliammeter 116. Then the switch is opened, thus placing the control circuit in operation. In general, the plate current of vacuum tube 90 will change when the switch is opened, since the grid voltage of this tube is dependent upon the control circuit. By varying the
316 grid voltage of the detector by potentiometer 98, the plate current of tube 90 is then adjusted to the normal value; and the apparatus is ready for operation. Upon receipt of an amplified signal at the detector, the effect of the control circuit is to decrease the plate current thru milliammeter 116, thereby reducing the amplification of the tube 90. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained, the plate current of tube 90 is at a minimum value.

It is believed unnecessary to explain the operation of the two radio-frequency amplification stages and of the detector, or of the two audio-frequency amplification stages,

for in operation they are substantially similar to those of the now well-known type of radio receiver employing neutralized two-stage radio-frequency and two-stage audio-frequency amplifiers. The control circuit operates, in the arrangement of Fig. 4, substantially in the same manner as in Figs. 1 and 3, to apply a negative biasing voltage to the grid of the radio-frequency amplifying vacuum tube 90, this voltage being a function of the radio-frequency voltage which has been amplified by the vacuum tubes 90 and 91 and then applied to the input circuit of detector 94. Since the voltage applied over conductor 111 is a function of the amplified radio-frequency voltage, there is a maximum, or cut-off, detector voltage determined by the constants of the circuit, as shown in Fig. 2, beyond which the radio-frequency amplifier is prevented from
317 effecting further amplification. This arrangement maintains the finally-amplified radio-frequency voltage at substantially constant value.

Fig. 5 shows an alternative system for coupling the detector to the first audio-frequency amplifying tube of Fig. 4. The coupling arrangement of Fig. 5 included within the dotted rectangle, when substituted for the corresponding portion enclosed within the rectangle of Fig. 4, provides a modified form of the invention. Corresponding elements of these two figures are identified by the same reference characters, from which it will be seen that Fig. 5 differs from Fig. 4 in that the transformer coupling between the detector 94 and the first audio-frequency amplifying tube 105 has been replaced by an impedance coupling arrangement including the condenser 117 and the impedance 118.

While this modification does not utilize a transformer having a step-up ratio such as is included in the arrangement of the former figure, it, nevertheless, introduces the advantage of effecting a more nearly constant degree of amplification at audio frequencies. When the modification of Fig. 5 is substituted in the system of Fig. 4, as described, the values of elements 104 and 101 may be the same as mentioned above; the resistance connected in lead 111 may be of 2 megohms; 118 of 2 megohms; 117 of 0.005 microfarads; and 113 of 0.5 microfarad.

Referring to Fig. 6, there is shown a radio receiver of the unneutralized type in which the so-called "A", "B" and "C" batteries have been replaced by a source of recti-

fied and filtered alternating current. In this em-
318 bodiment of the invention there are provided three
stages of tuned radio-frequency amplification in which the vacuum tubes of the successive stages are designated 119, 120 and 121, respectively. These several stages are transformer-coupled; and the last stage of the amplifier is coupled to a three-electrode vacuum tube detector 122, the grid bias voltage of which is controlled by potentiometer 128. In the output circuit of detector 122, there is provided a rejector circuit, similar to that previously described, for filtering out radio-frequency currents that have passed thru the detector; and also an audio-frequency network, or impedance coupling, including condenser 123 and impedance 124, for passing the audio-frequency component of the rectified signal to the first audio-frequency amplifying vacuum tube 125. The filament of this tube is shunted by rheostat 129 which functions as a manual volume control. This last tube is transformer-coupled to a second stage of audio-frequency amplification, including the vacuum tube 126, in the output circuit of which there is provided a loud speaker, or other suitable indicating device, 127, which on occasion may be replaced by a coupling device in a telephone system. The filaments of these six vacuum tubes are connected in series across a suitable resistance in the rectified, filtered source of power supply, giving a potential difference of 30 volts, thus taking the place of an "A" battery. The necessary "C", or bias, voltage is derived
from a potential difference across a resistance in
319 that portion of the power supply indicated by the
reference character "C", while the plate-current supply is similarly derived from a resistance in that portion of the power supply indicated by the reference letter "B". It should be noted that the filament of the first radio-frequency amplifying tube 119 is connected to the positive terminal of the 30-volt "A"-section of the power source, and that the filament of the detector tube 122 is connected to the negative terminal of this section. The constants of the elements of this embodiment may in general be similar to those suggested with reference to Fig. 5.

In adjusting the receiver of Fig. 6, the potentiometer 128 is adjusted with switch 115 open, as described in connection with the adjustment of the receiver of Fig. 4. This arrangement with the vacuum tube filaments connected in series obviates the necessity of a separate battery corresponding to 100 of Figs. 4 and 5, since the plate of the detector tube 122 can be positive relative to the filament of that tube, and at the same time maintains the grid of the first radio-frequency amplifying tube 119 negative relative to the filament of the same tube, due to the difference of potential between the two filaments. Thus the biasing voltage applied to the control-grid is derived from the voltage across the filaments instead of from a battery as in Figs. 4 and 5.

In Figs. 4 and 5, batteries "B" and 100 are connected in
series in the plate circuit of detector 94 and both contribute
to the detector plate current. The "B" battery supplies
the voltage drop in resistor 101, while battery 100 supplies
the plate voltage of detector 94. The presence in the
320 detector plate circuit of the "B" battery, which is
directly connected to the grounded filament circuit,
in addition to auxiliary battery 100, allows the use of a high impedance 101 in the detector plate circuit with a resulting high sensitivity of the detector circuit. The same result is achieved in the arrangement of Fig. 6 by the cooperation of the "A" and "B" voltages in the detector plate circuit, as described before. In the event that tubes having an indirectly heated cathode are used instead of those having an incandescent filament cathode as represented in the figure, the same advantages may be obtained as pointed out in connection with Figure 6, if the detector cathode is maintained at a potential much more negative than the cathode of the controlled tube or tubes, which, in the figures, is the first radio-frequency amplifier tube.

The circuit arrangement shown in Fig. 7 incorporates several advantages introduced by the present invention, some of which have been individualy described above. Briefly, this arrangement includes a combination of the features illustrated in and described in connection with Fig. 3 and Fig. 6. The reference characters of Fig. 7 correspond to those employed in Fig. 3 and have the same significance. It will be noted in addition to the apparatus represented in Fig. 3, that there is here illustrated a power source of rectified and filtered alternating current which replaces the so-called "A" and "B" batteries represented

in Fig. 3, and, in addition, includes a source of "C",
321 or grid bias voltage for tube 79. The grid of tube
77 is biased by connecting the "grid return lead" to an appropriate point in the series-filament circuit, as shown. The power source is similar to that shown in and described in connection with Fig. 6. The present arrangement thus includes the advantages of neutralized radio-frequency amplifying stages, automatic volume control applied to the first two stages of the radio-frequency amplifier, a two-electrode valve, or rectifier, and the complete elimination of all batteries for supplying operating potentials to the system. As is also true of the arrangement of Fig. 6, the automatic volume control not only compensates for fluctuations in the strength of the incoming signals, but also compensates for reasonable variations in line voltage of the alternating current power supply.

As in Fig. 6 the variable tuning condensers C_1-C_4 are grounded in order to eliminate undesirable capacity effects as well as to make it practicable to connect the condensers on a single shaft for uni-control, if desired. As in Fig. 6, it will be seen that the power supply of Fig. 7 is not grounded, thus eliminating the danger of short-circuiting the direct-current supply when a separate ground is necessary for the alternating-current rectifying and filtering system. In certain instances, Figs. 6 and 7 differ in the connection of certain by-pass condensers. The purposes and reasons for the positions of these by-pass condensers should be apparent to those skilled in the art.

322 Assuming that the vacuum tubes employed are of the type having five-volt filaments, 35 volts of filament, or "A", supply is needed. As above mentioned, the automatic volume control is here applied to two tubes, namely 58 and 60; the cut-off being effected with the use of two different plate, or "B", voltages. The plate electrode 66 of rectifier 64 is more negative relative to the filament of tube 58 than relative to the filament of tube 60, by the 5-volt drop across one filament. To compensate for this difference, 35 volts higher "B" voltage is applied to the plate of tube 58 than to the plate of tube 60, which makes both tubes cut off practically at the same time. The reason for applying a "B" voltage of 85 volts (which, of course, is to be added to the 35 volts "A" voltage) to the

plate of tube 60, whereas a "B" voltage of 90 volts is applied to the plates of the radio-frequency amplifying tubes of Fig. 6, is that the arrangement of Fig. 7 employs one more tube than Fig. 6; the difference of 5 volts being included in the "A" supply, as will be seen by comparing the two figures. Thus, actually, the plates of the radio-frequency amplifying tubes 119, 120 and 121 of Fig. 6 are provided with 90, 95 and 100 volts, respectively. Similarly, the plates of the amplifying tubes of Fig. 7 are supplied with 85 to 155 volts.

In addition to the combined advantages just outlined, the arrangement of Fig. 7 also includes an additional feature which has not previously been described, namely, the means 130 for determining the filament current supplied to one of the amplifying tubes. As has been explained
323 in connection with Fig. 6, when operating the filaments of the several vacuum tubes on rectified and filtered current from an alternating current power source, it is desirable that the filaments be connected in series since it is at present more practicable to provide a current supply at a comparatively high voltage and low current. Fig. 6 shows a shunt rheostat 129 connected in parallel with the filament of tube 125 so that the current divides between the rheostat and the filament. While this means for controlling the filament emission of a single tube, as shown in Fig. 6, is fairly satisfactory, the arrangement shown in Fig. 7 is a substantial improvement. With the former method, an increase in current thru the controlled filament is accompanied by a smaller increase in current thru the other filaments in series. The improved arrangement shown in Fig. 7, on the other hand, by providing three resistances, two of which are simultaneously variable, allows a variation of the voltage on one or more filaments without affecting the current thru the other filaments; or, more generally, without changing the load on the filament-current supply. It is apparent that the benefits of this device will be especially manifest in an arrangement such as the present, wherein the current supply for the filaments is obtained from a rectified, filtered alternating current source, particularly when the rectifying device is of the common type without automatic voltage regulation. The compound rheostat 130 comprising resistances R_1 and R_2 is so arranged that a move-

ment of the control knob will increase the one resis-
324 tance, while diminishing the other in proportion.

One of these resistances, namely R_1, is connected in series with resistance R_0 in shunt with filament 74 of tube 71, the resistance of filament 74 being represented by "R_f". It may here be pointed out that while Fig. 7 illustrates the manual control of the filament of only one tube, namely 74, the filaments of other tubes could be connected either in series or parallel with filament 74 if it were desired that independent simultaneous control be had of more than one filament. "R_f" may, therefore, be taken to represent the effective resistance of the filaments to be controlled. When the two resistances R_1 and R_2 and the fixed resistance R_0 are properly proportioned to the normal operating resistance R_f of the filament or filaments of the tubes to be controlled, the resistance of the system as a whole will remain substantially constant during adjustment of the control device 130. By way of illustration, the following data are given for Fig. 7, assuming the tubes to be all of the well-known 201A type, each filament being of 20 ohms resistance: R_f will equal 20 ohms; R_0 may equal R_f; R_1 may equal $8R_f$; and R_2 may equal $\frac{1}{2}R_f$. Accordingly, to control one tube when R_f equals 20 ohms, R_0 will equal 20 ohms, R_1 will equal 160 ohms, and R_2, 10 ohms.

It is believed unnecessary to describe the method of controlling the signal amplification in the arrangements of Figs. 5, 6 and 7 since they are substantially similar in operation to that of the systems described in reference to Figs.
1, 3 and 4. It should be mentioned, however, that
325 the advantages of the present invention are espe-
cially apparent in systems such as shown in Figs. 6 and 7, because of the fact that any reasonable fluctuations in the voltage of the power supply line are thus automatically compensated for, and uniform volume of signals is assured.

There are advantages attending the use, in connection with the present invention, of the two-electrode rectifier circuit typified by Figs. 1, 3 and 7, which may not be apparent from the foregoing discussion. It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say ten volts, so that the latter condition of large signal voltage is realized. No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of voltages. This distinction will be seen from Fig. 8 where the abscissae "A. C." represent the alternating signal voltages, whereas the ordinates "D. C." represent the rectified output voltages. It is well known that the linear curve is much more desirable when minimum distortion of a modulated signal is desired, and it will be observed from Fig. 8 that the preferred type of curve is obtained from the two-electrode rectifier.

326 The three-electrode detector is useful for relatively small applied voltages, and the rectified output voltage is then approximately proportional to the square of the applied voltage, i. e., to the power associated with the applied voltage. For this reason the rectified voltage increases with the carrier wave modulation. When such a detector is used in the control system, as in Figs. 4, 5 and 6, the total power from the radio-frequency amplifier is maintained at a substantially constant level, the amplitude of the carrier wave being decreased in the presence of modulation. It is desirable to maintain the carrier wave at a constant amplitude at the output of the amplifier, and this is accomplished by the two-electrode rectifier as shown in Figs. 1, 3 and 7. The control system maintains constant the average signal amplitude which is equal to the carrier wave amplitude and independent of the degree of modulation.

It will be observed that in a system employing a two-electrode rectifier such as represented by valve 33 of Fig. 1, and 64 of Figs. 3 and 7, the control bias voltage is independent of the "B" or anode battery voltage. Since the rectifier is not an amplifier, is not critical, and requires neither anode nor biasing battery, no adjusting devices are required. This is not the case in the three-electrode detector circuits, so that a potentiometer, 98 or 128 in Figs. 4 or 6, respectively, must be adjusted as described to accommodate the control bias to any particular combination of tubes and "B" voltage. On the other hand, the latter type of detector is more sensitive because it is also an amplifier,

327 so that the control system operates on a smaller applied alternating voltage.

In the foregoing description, tuned radio-frequency receivers of the neutralized and unneutralized types have been referred to. It should be pointed out, however, that the present invention may be employed with equal effectiveness to any radio receivers in wired radio and space radio systems, and that it has been found especially applicable to receivers of the superheterodyne type. For this reason the present disclosure of typical embodiments of the invention should not be construed as a limitation, but merely as illustrative of the principles of the invention, the scope of which is defined in the appended claims.

328 *Claims in Suit.*

Any Claims May Be Cancelled if Court Requests.

68. In a radio receiving system responsive to signals which may have any intensity within a wide range, a signal translating system including a vacuum tube having an anode circuit, a detector which produces a rectified component of said signal, means causing said rectified component to vary the anode current of said tube in correspondence with the received signal intensity, and means responsive to said anode current for visually indicating variations of received signal intensity.

69. In a radio receiving system responsive to signals having a large range of input intensities, an automatic control electrically linking portions of said system for maintaining the signal output intensities of said system within a small range, and means of small range for visually indicating said output intensities and thereby automatically indicating said input intensities.

72. In a signaling system including a multistage vacuum tube amplifier tunable to resonance with a signal frequency, the combination of means for automatically maintaining the amplified signal intensity substantially constant whereby audible indication of resonance is impracticable, and means for visual indication of resonance comprising a current-indicating device which responds to variation in the plate current of one or more of said amplifier tubes.

329 73. A receiving system for high-frequency currents comprising tuning means for causing the system to respond to current of desired frequency, means for producing an audible response to modulations in the re-

ceived current which is of constant volume over a range of variation of intensity of high-frequency current at said desired frequency, and visual means for indicating when the tuning means is in proper adjustment for control of said audible response by said second means over the maximum range of said variation in intensity.

74. In a high-frequency receiving system, an electron discharge device having an anode circuit, a cathode and a grid, a tuned circuit connected between the cathode and grid whereby the receiving system may be adjusted to respond to current of desired frequency, sound reproducing means, means for supplying current from the device to said sound reproducing means, means for controlling the static potential on the grid in response to the intensity of the received current thereby to produce a substantially constant volume of sound from the sound reproducing means over a range of intensities of received current, and means responsive to the magnitude of current flowing in the anode circuit for visually indicating the condition of adjustment of the tuned circuit with reference to the frequency of received current, whereby said tuned circuit may be adjusted in accordance with said last named means independently of the audible indication supplied by the sound reproducing means.

330 75. In a signaling system including a vacuum tube amplifier tunable to resonance with the frequency of the received signals, the combination of means for adjustably tuning said system to resonance with a signal frequency, means for automatically maintaining the amplified signal intensity substantially constant by control of the plate current of said amplifier, whereby the usual audible indication of resonance is impracticable, and a milliameter connected in the plate circuit of one or more of the automatically controlled vacuum tubes of said amplifier, resonance being visually indicated by minimum current through said meter.

76. In a modulated-carrier-current signaling system including a vacuum tube amplifier adjustably tunable to resonance with the carrier-current frequency and a rectifier coupled to the output of said amplifier for detecting the modulations, the combination of means for automatically maintaining the modulation signal intensity substantially constant during fluctuation of the received carrier-current by automatic control of the plate current of said amplifier,

and indicating means directly actuated by change in plate current of said vacuum tube amplifier for indicating a condition of resonance of the vacuum tube amplifier with the carrier-current frequency.

77. In a modulated-carrier-current signaling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct current connection from said rectifier to an element
331 of said amplifier for applying to a control electrode of said amplifier a biasing voltage derived from the output circuit of said rectifier, whereby amplification is regulated automatically, and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified, said carrier-current amplifier being tunable to resonance with the carrier-current frequency, and means responsive to the carrier-current for visual indication of resonance.

Fig. 1,

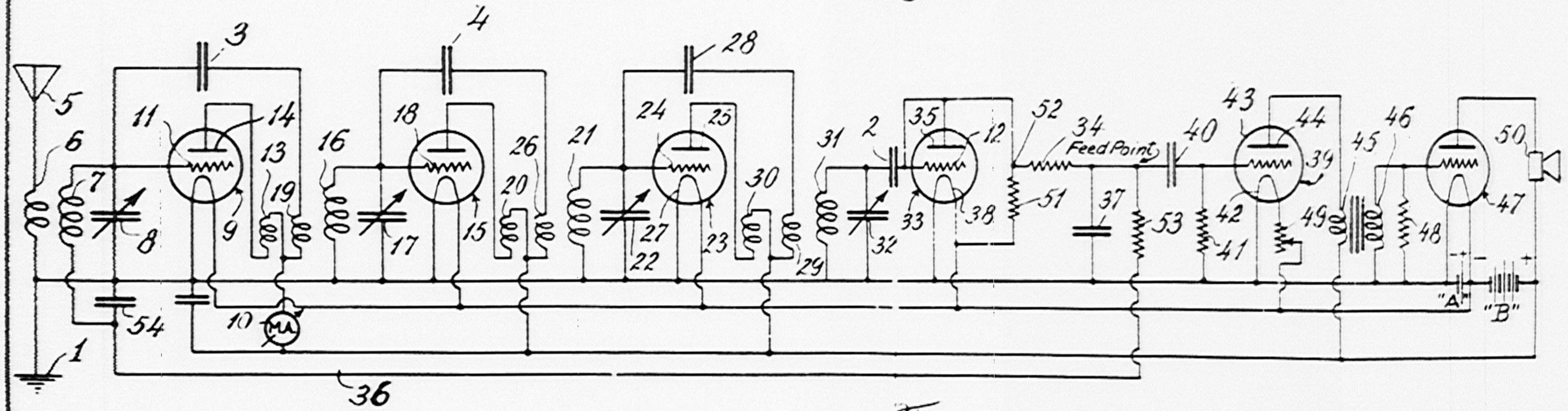
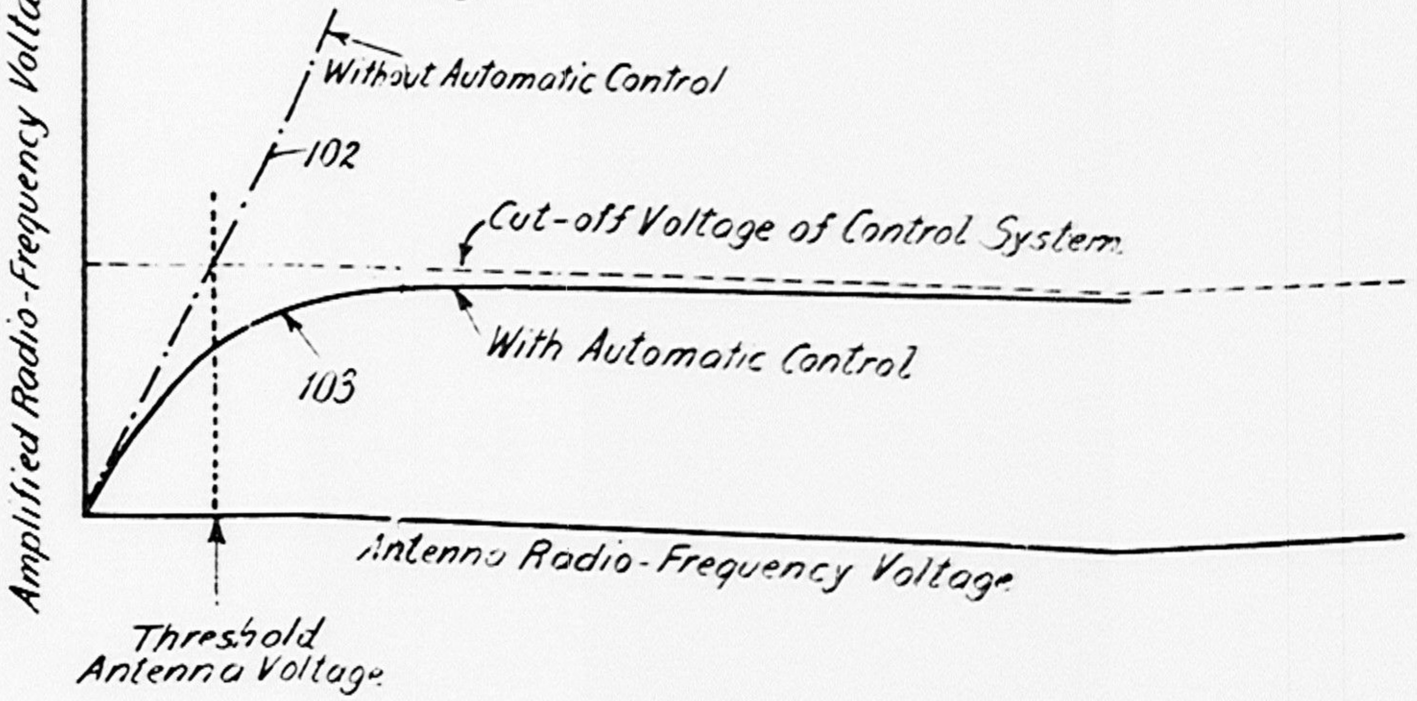


Fig. 2,



INVENTOR
Harold A. Wheeler
BY
Pennie, Davis, Marvin & Edmonds.
ATTORNEYS

Fig. 3,

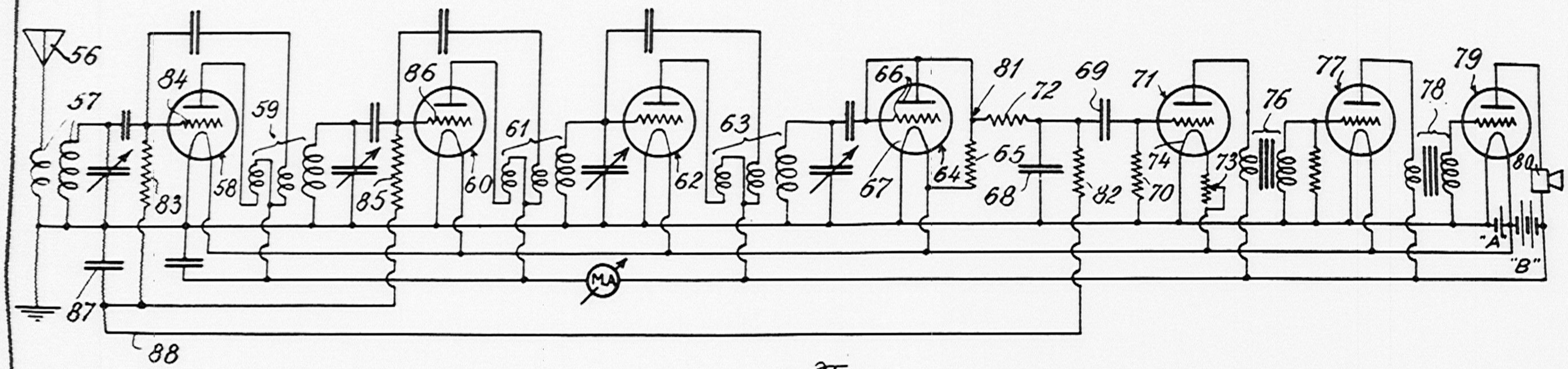
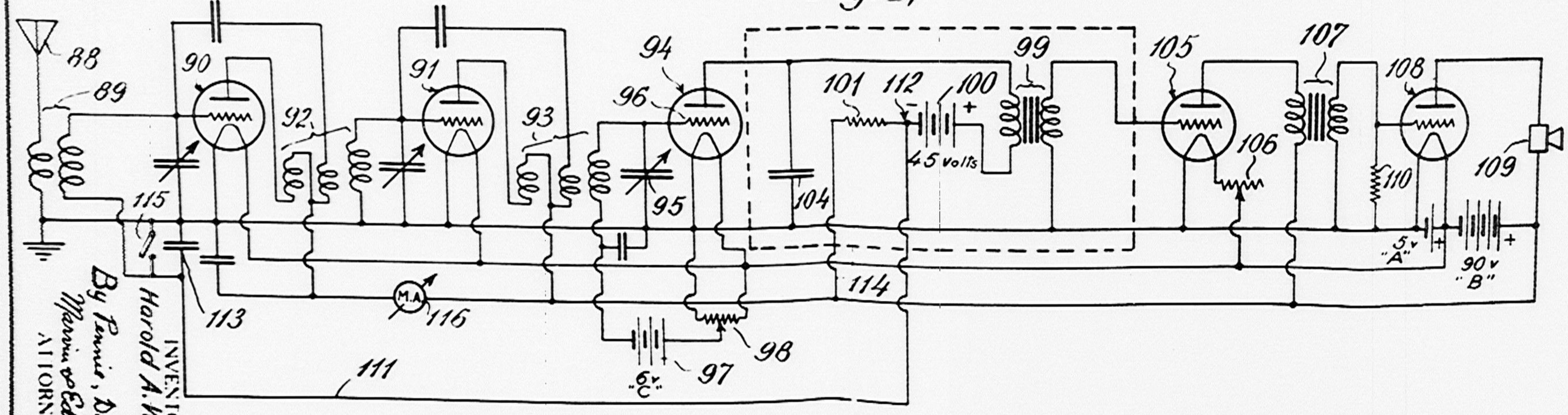


Fig. 4,



INVENTOR
Harold A. Wheeler
By Rennie, Davis,
Marvin & Edmonds,
ATTORNEYS

Fig. 5,

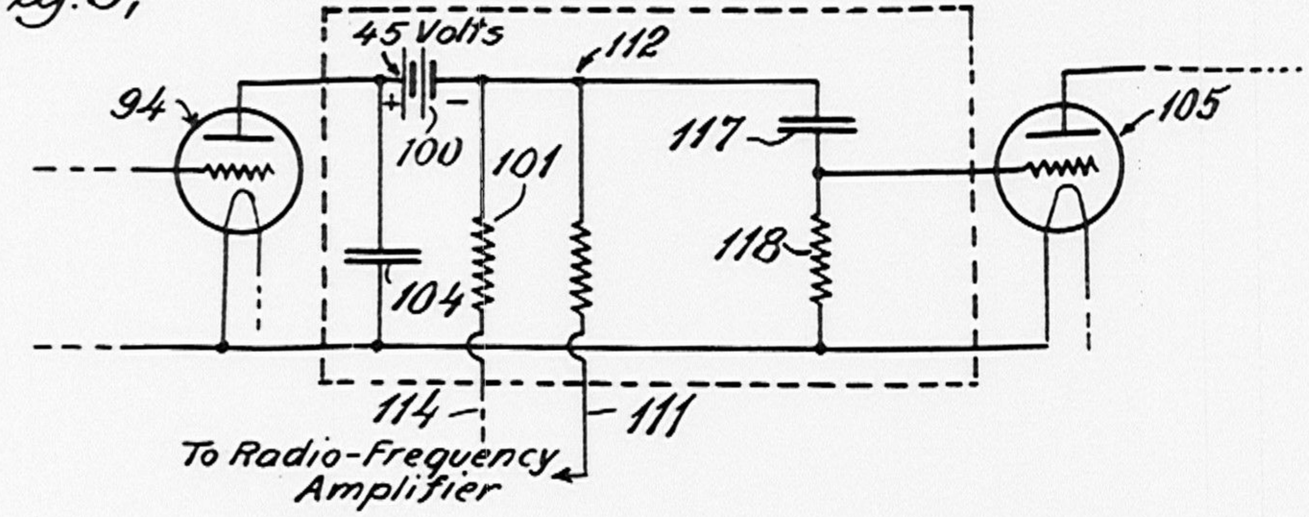
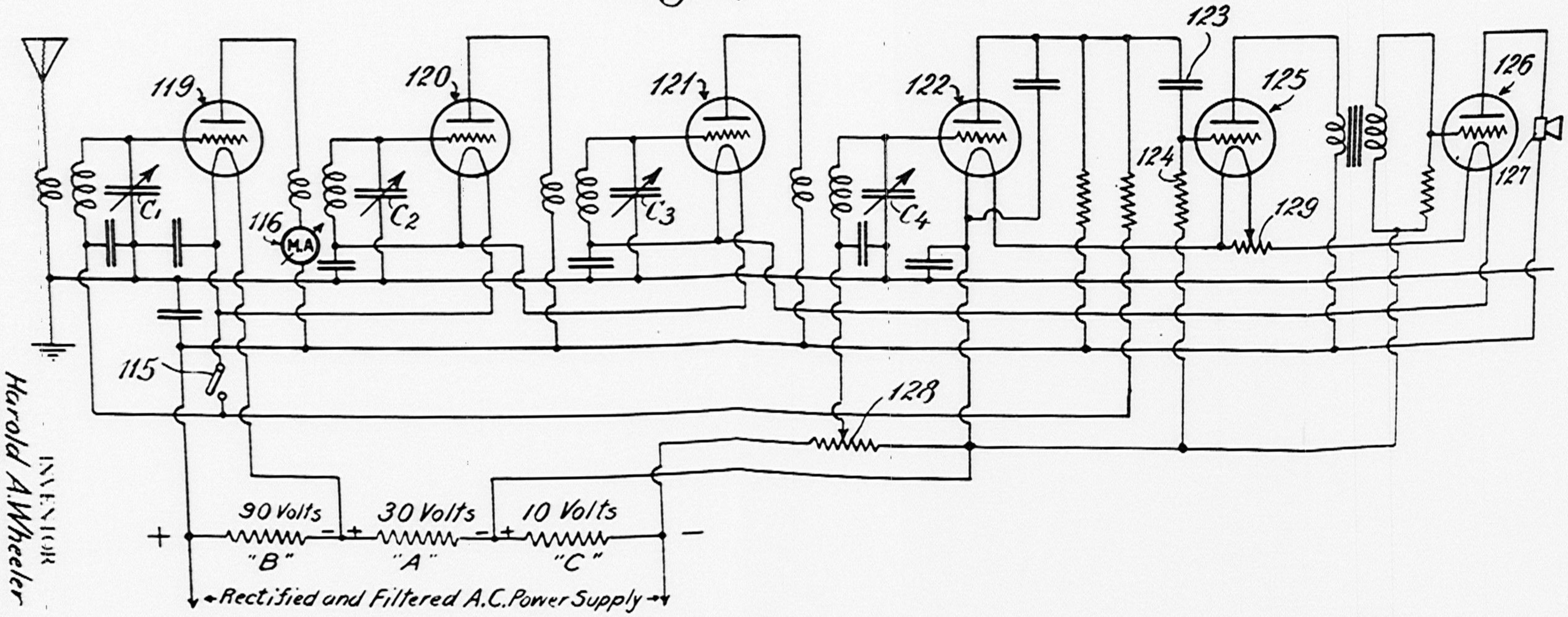


Fig. 6,



INVENTOR
Harold A. Wheeler
BY
Pennie, Davis, Marvin & Edmonds
ATTORNEYS

Fig. 7,

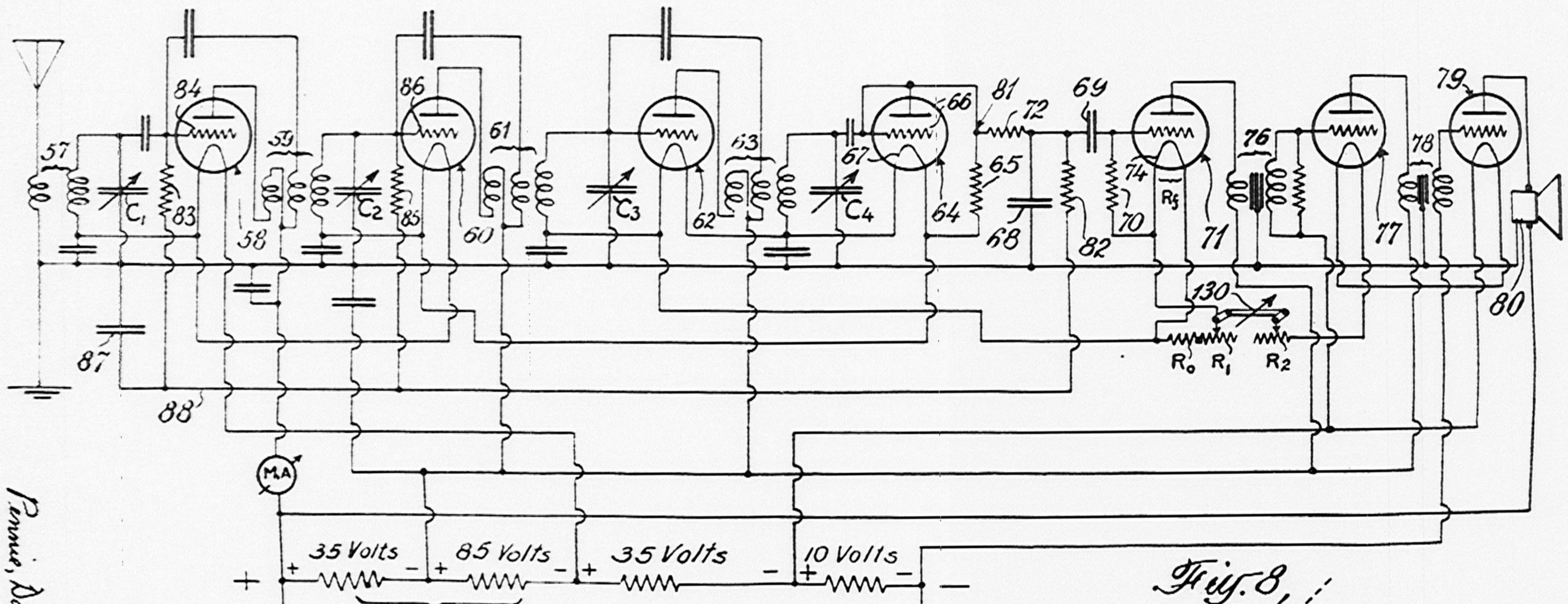
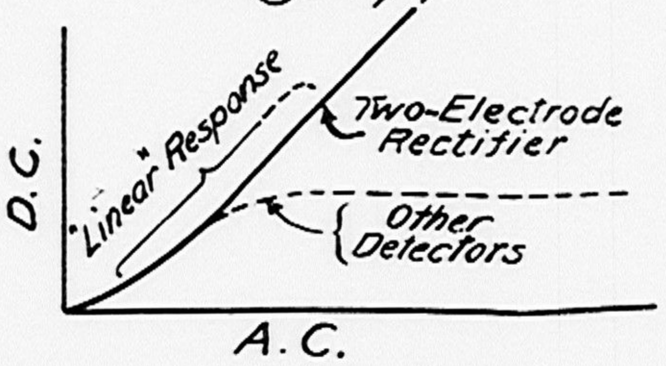


Fig. 8,



Harold A. Wheeler
INVENTOR
BY
Pennie, Davis, Marvin and Edmonds.
ATTORNEYS

Plaintiffs' Exhibit 6A.

Proceedings of the Institute of Radio Engineers
Volume 19, Number 4 *April, 1931*

A RADIO BEACON AND RECEIVING SYSTEM FOR BLIND LANDING OF AIRCRAFT*

By
H. Diamond and F. W. Dunmore
(Bureau of Standards, Washington, D. C.)

Summary—*A radio beacon and receiving system is described for use at airports to permit the blind landing of aircraft under conditions of no visibility. The system comprises three elements to indicate to the pilot the position of the aircraft as it approaches and reaches the instant of landing. Lateral position (that is, landing field runway direction) is given by a small directive beacon of the same type as employed for guidance on the airways, differing only in the use of smaller loop antennas and lower power. Longitudinal position along the runway (that is, approach) is given by a marker beacon. Height is given by an inclined ultra-high-frequency radio beam, used in such a way as to provide a very convenient gliding path for the landing airplane, free of all danger from obstructions.*

The same medium-frequency receiving set required for obtaining radiotelephone and radio range beacon service on the airways is utilized for receiving the runway localizing and marker beacon signals. The course indications of the runway localizing beacon are observed on the same vibrating reed indicator as employed on the main radio range beacon, automatic control of receiving set sensitivity being provided to maintain substantially constant reed deflections regardless of the distance between airplane and transmitting station. The marker beacon indications are received aurally. A special high-frequency receiving set is required to receive the landing beam signals. The rectified output current of this set is passed through a d-c microammeter mounted on the instrument board. By keeping the deflection of this microammeter at a fixed value, the pilot directs the airplane along the curved path coinciding with the line of equal intensity of received signal below the axis of the beam. The relative position of the airplane with respect to this convenient landing path is indicated by the rise or fall of the microammeter deflection above the fixed value.

I. Introduction

THIS paper describes the research on a radio system for the blind landing of aircraft carried on in the Research Division of the Aeronautics Branch of the Department of Commerce at the National Bureau of Standards, during 1928 to 1930.

The object of the research was to provide a simple and effective radio system which, when combined with the usual navigational instruments, would permit the safe landing of aircraft in fog or any condition of visibility or no visibility. This system was to be adaptable for use in conjunction with the radio navigational aids being provided for point-to-point flying on the civil airways of the United States. In ac-

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* Decimal classification: R526.30. Original manuscript received by the Institute, August 27, 1930. Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce.

a line of constant field intensity is followed no control of volume is necessary.

2. Experiments Leading to Development of Landing Beam.

At this point, it may be of interest to describe the experiments which led to the development of the landing beam. The object of the first experiments along this line, early in 1929, was to mark out an equisignal path in space similar to that obtained with the visual type beacon, but making a constant angle with the horizontal, that is, with the ground. To this end the same transmitting set-up as for the localizing beacon was employed, the two crossed loop antennas being turned over on their sides. This experiment proved unsuccessful because of ground reflection phenomena on the long waves used (about 300 kc).

The next step was to employ directed waves of higher frequencies. Ultra high frequencies, of the order of 60 to 100 megacycles, were chosen in order to reduce the size of the antenna arrays Two beams were required, both of the same radio frequency but each modulated to a different low frequency, and its axis making a different small angle with the horizontal. The equisignal zone would therefore occur where the two beams intersected, i.e., along a line making an angle with the ground intermediate to the two angles formed by the axes of the two beams and ground. It was recognized that some difficulty would be met in setting up the transmitting circuit arrangement necessary for this system, on the ultra high frequencies considered, since a common master oscillator feeding two balanced amplifier branches, each modulated to a different low frequency, was required. Moreover, making use of the equisignal zone, once it was set up, would add another volume control for the pilot to adjust as he approached the point of landing. The construction of suitable apparatus was, however, begun.

It was at this stage of the development that one of the authors[8] conceived the idea of using only one high-frequency beam in the manner described in section III-1 thereby eliminating the technical difficulties noted and at the same time providing a more suitable gliding path for the landing airplane. The obvious simplification of equipment both on the ground and on the airplane led to the adoption of this idea.

3. Other Improvements.

a. Runway Localizing Beacon. The runway localizing beacon employed in the improved system of blind landing aids, while still operating on the same principles as previously, has been made considerably easier to use. At the receiving end, some difficulty in following the course was experienced owing to the necessity for adjusting the receiving set sensitivity as the airplane approached the beacon transmitter. Since the beacon signals are followed from a distance of five miles from the transmitter to approximately 2000 feet from the transmitter (the point of landing), variations in the field intensity of the order of 25 to 1 obtain. Continuous adjustment of the receiving set volume control was therefore necessary, in order to keep the reed deflections within scale. The pilot, in making a landing, is, however, concerned with so many things that keeping the necessary close adjustment of the receiving set sensitivity becomes a troublesome task. To overcome this difficulty, an automatic volume control device was developed for maintaining essentially constant receiving set output voltage regardless of the magnitude of the input voltage. The use of the runway localizing beacon thereby resolved itself simply to observing the course indications on the reed indicator and maneuvering the airplane to keep on the course. The automatic volume control device operates through rectification of the alternating voltage across the reed indicator terminals and application of the rectified voltage, after filtering, as a negative biasing voltage on the grids of the radio-frequency amplifying tubes of the receiving set. An increase in the input voltage to the receiving set normally tending to increase the voltage across the indicator terminals is, therefore, accompanied by an increase in the negative bias on the radio-frequency amplifying tubes and, consequently, by a reduction in the receiving set sensitivity such as to maintain substantially constant voltage across the reed indicator.

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[8] F. W. Dunmore.

The provision of this automatic volume control device made possible the addition of an important instrument on the airplane instrument board, giving the pilot information as to his approximate distance from the localizing beacon transmitter. Since increasing input voltage to the receiving set is accompanied by increasing negative biasing voltage on the grids of the radio-frequency amplifying tubes, the deflection of a direct-current milliammeter connected in the plate circuit of these tubes will decrease as the airplane approaches the beacon transmitter. This meter (see Fig. 10) may therefore be calibrated directly in approximate distance from the transmitter. Its calibration will hold roughly on different localizing beacons at different airports, provided these beacons are of approximately the same power ratings. Its chief function is, however, to give the pilot an added check that he is approaching or departing from the landing field and should aid materially in avoiding confusion during blind flight.

b. Boundary Marker Beacon. In the first arrangement of blind landing aids, the boundary marker beacon signals were received on the airplane on a special reed indicator connected in series with the vibrating reed course indicator. Several factors combined to point out that aural indication might prove preferable in this case. The pilot, during landing, must focus attention on a number of instruments giving continuous information as to course, altitude of the airplane, air speed, etc. It was felt that he might easily miss the indications given by the marker beacon reed during the short period when he passed over the landing field boundary line. Aural indication would preclude this possibility The marker beacon modulation was therefore changed to 1000 cycles. Using automatic volume control, it is required to hold the voltage across the vibrating reed course indicator constant, while the marker beacon signal must be permitted to vary through a minimum. This requirement was met through the use of a filter circuit arrangement connected in the receiving set output which served to direct frequencies below 200 cycles to the reed indicator and frequencies above that value to the head telephones. The automatic volume control device is connected across the reed indicator terminals as before and, consequently, is operated only by the signals from the localizing beacon (no voltage of 1000-cycle frequency appearing across the indicator). The 1000-cycle marker beacon signal heard in the head telephones, since it does not affect the automatic volume control device, is therefore permitted to vary through a minimum, as required.

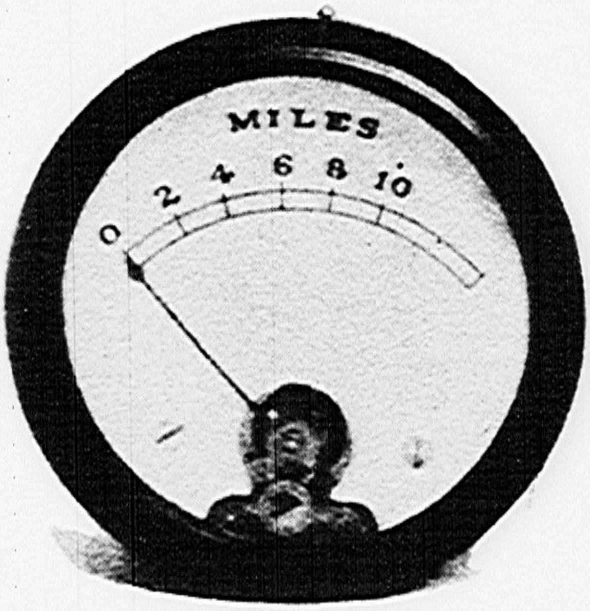


Fig. 10—Rough distance indicator used on the pilot's instrument board to show the approximate distance of the airplane from the runway localizing beacon transmitter.

lined housing which supports the receiving dipole antenna structure *H*, and an amplifier-rectifier unit *I*. The rectified output current is fed to the landing beam indicator *J*. The remote control panels for the medium-frequency and ultra-high-frequency sets are shown at *K* and *L*, respectively. *M* contains the batteries necessary for operating these sets.

A photograph of the instrument board on the Bureau's experimental airplane is shown in Fig. 12. The reed indicator is shown at *A*, the landing beam indicator at *B*, and the rough distance indicator at *C*. At *D* is shown the control panel for the landing beam receiving set. The control panel for the medium-frequency receiving set is not shown.

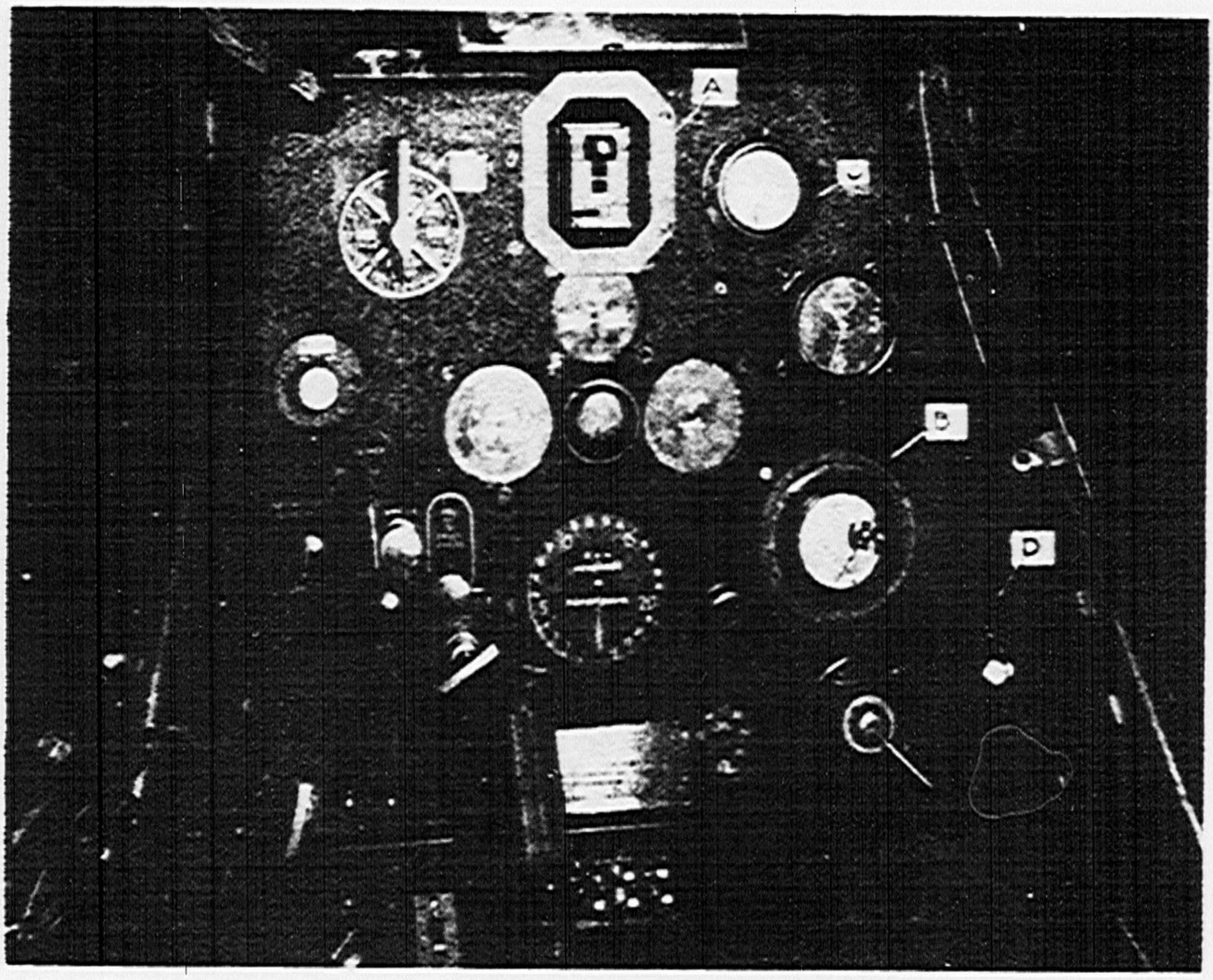


Fig. 12—Instrument board on Bureau of Standards' experimental airplane, showing vibrating reed course indicator *A*, landing beam indicator *B*, rough distance indicator *C*, and landing beam runway set control and test panel *D*.

Let us now consider the operations required on the part of the pilot in making a blind landing. It is assumed that the information necessary for maintaining the airplane in stable flight is available through the use of suitable flight instruments. The medium-frequency receiving set is tuned to the frequency of the main radio range beacon (say, Plaintiffs' Exhibit 6B.

U. S. DEPARTMENT OF COMMERCE
AERONAUTICS BRANCH

AIR COMMERCE BULLETIN

ISSUED SEMIMONTHLY

Vol. 2. Washington, August 15, 1930 No. 4

CONTENTS

A radio system for blind landing of aircraft.
Final estimate on aircraft production for first six months of 1930.
Status of aircraft, pilots, and mechanics, by States.
General aeronautic developments:
- Weekly airport information service established.
- Aeronautics Branch has issued 48 glider pilot licenses since first of year.
- Index published for all airway bulletins issued by Department of Commerce.
- Number of airports and landing fields in the United States as of August 1, 1930.
- Aeronautic radio research.
- Names of physicians authorized by Aeronautics Branch to examine airmen listed in printed bulletin.
- Amendment to revised regulations governing establishment and certification of aeronautical lights.

General aeronautic developments—Contd.
- Aeronautical reference material listed in revised bulletin.
- Calendar of coming events.

Notices to airmen and aircraft operators:
- Airport and airway changes and warnings.
- Airway progress.
- Certified aeronautical lights.
- New airway bulletins.
- Airway bulletins withdrawn from circulation.
- Recent air markings.
- Proposed airports.
- Airports no longer proposed.
- New airport and landing field data sought.

Licenses, identifications, and approvals:
- New approved-type certificates.
- Revisions in the approved-type certificates.
- Airplane approvals without A. T. C.

United States air-transport routes.

A RADIO SYSTEM FOR BLIND LANDING OF AIRCRAFT

Since the fall of 1928, the aeronautics research division of the Aeronautics Branch at the Bureau of Standards has been conducting experiments on a radio system for the blind landing of aircraft.

The object of the research was to provide a simple and effective radio system which, when combined with the conventional navigational instruments would permit the safe landing of aircraft at airports and landing fields under conditions where little or no visibility existed.

Such a system of blind-landing aids must, in general, indicate to the pilot the position of the aircraft in three dimensions as it approaches and reaches the instant of landing. In accordance with the practice already adopted in the development of the navigational aids for the civil airways, all the complicated and expensive parts of the system were to be used on the ground, the equipment required on the aircraft being kept as simple as possible.

The system developed fulfills these requirements. The pilot receives the desired information with a minimum of effort on his part. The additional equipment required on the aircraft for use of the blind-landing aids is very simple, weighing approximately 15 pounds.

The practicability of the use of directional radio as an aid to point-to-point flying has been demonstrated by nearly two years of service given by the radio-range beacon system on the Federal airways. By means of this system the pilot can keep accurately on his course, know approximately the points he is flying over, and proceed unerringly to his destination. Scheduled air-transport operation is thus immeasurably aided; many flights are undertaken which doubtless could not succeed without the use of radio-direction facilities.

mast antenna are sufficient to receive all these indications except the landing-beam signals, for which a special high-frequency receiving set is provided. This high-frequency set employs a horizontal doublet antenna, about 5 feet long.

This one medium-frequency set with visual radio range beacon reed indicator (fig. 3) and automatic volume control may be utilized to receive the beams from the main radio range beacon and also the runway localizing beacons. By the use of a special filter circuit, reception of the aural boundary marker beacon is permitted while the reeds on the visual beacon indicator are functioning. An approximation of the distance away from the transmitter is determined by the rough-distance indicator, which is an adaptation of the conventional tuning meter on receiving sets provided with automatic volume control (fig. 4). This also is operated from the one set.

The main beacon *A* and the localizing beacon *B* are of the visual type, the essential difference between the two being the number of beacon courses radiated, the power ratings of the final amplifying stages, and the dimensions of the loop antennas. A description of the visual-type beacon is given in AIR COMMERCE BULLETIN, May 15, 1930. Briefly, the two loop antennas, crossed at 90°, carry currents of the same carrier frequency but modulated to different low frequencies, 65 and 86.7 cycles, respectively. On the airplane a visual indicating instrument is employed, consisting of two vibrating reeds mechani-

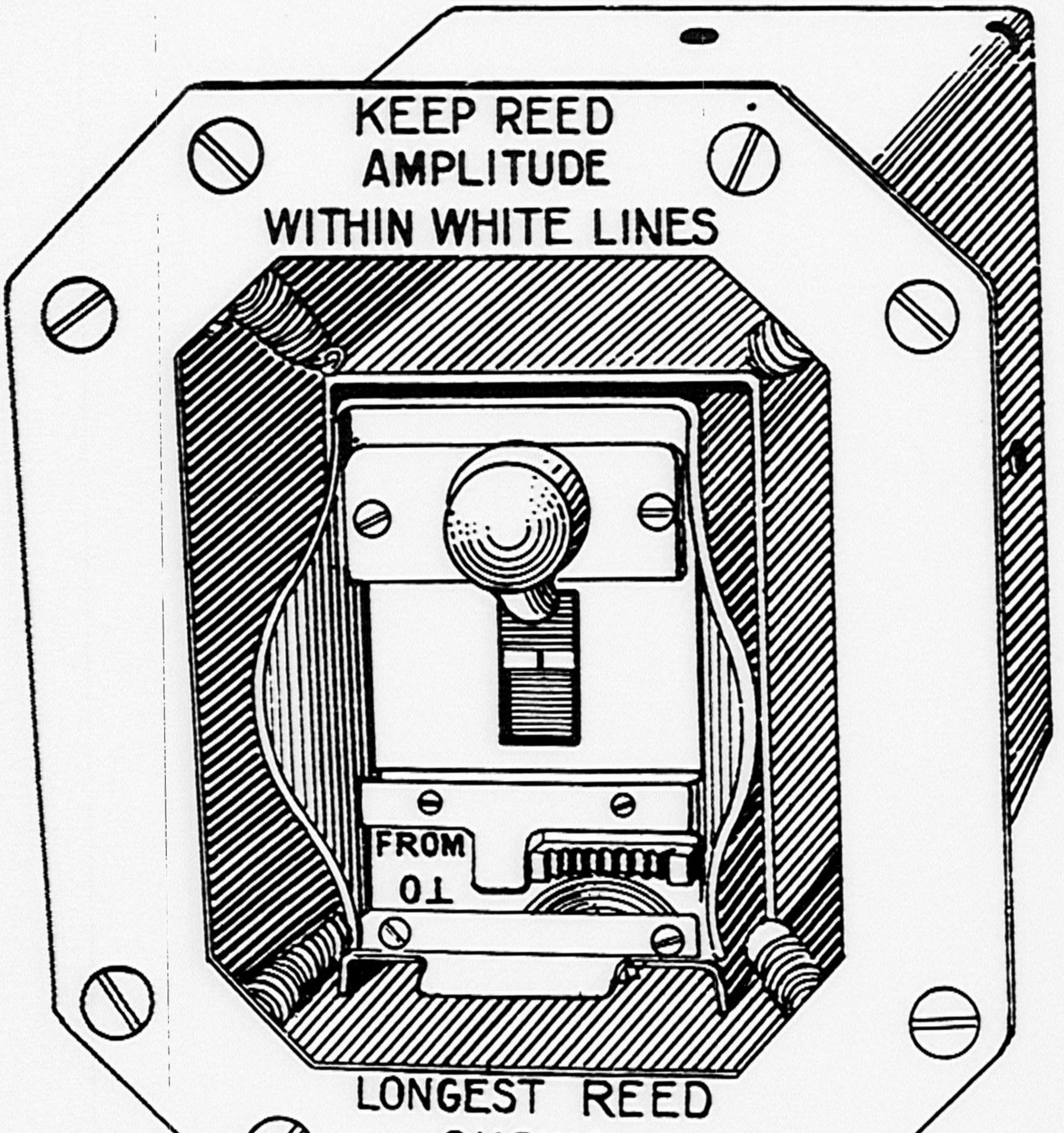


FIGURE 3.

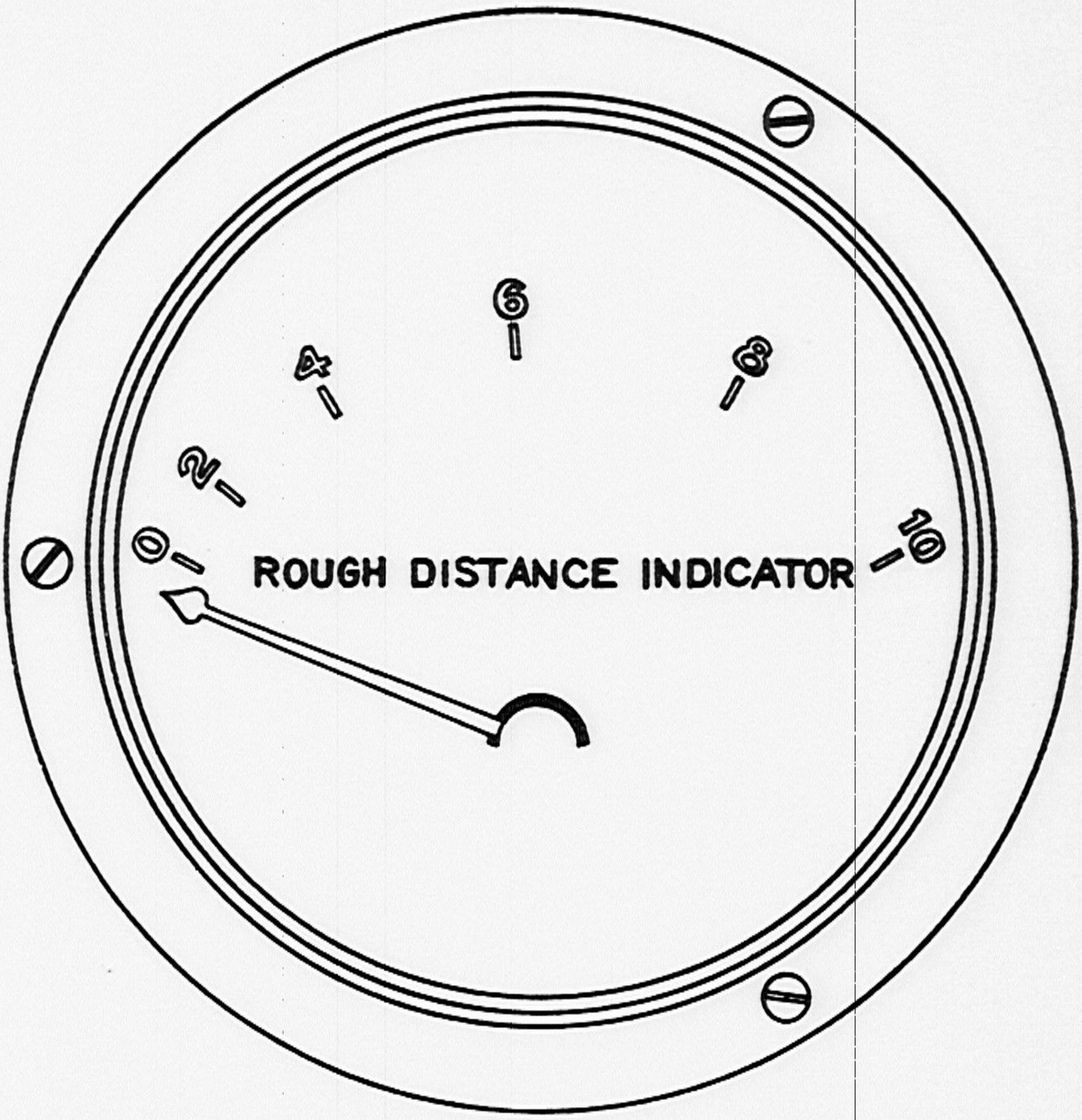


Figure 4.

cally turned to these two low frequencies and actuated by small electromagnets connected in the output circuit of the receiving set. When the beacon signals are received the two reeds vibrate, comparison of their relative amplitudes of vibration serving to indicate the relative amount of signal received from the two loop antennas. On course—that is, along the lines bisecting the angle between the two antennas—the reed vibration amplitudes are equal. Off the course they are unequal, the reed vibrating with the greater amplitude being on the side to which the airplane has deviated.

By adjusting the time-phase displacement between the carrier currents in the two loop antennas, the number of courses provided by the beacon may be made either 2 or 4. The 4-course arrangement is more convenient for use on the fixed airways. However, the 2-course connection is more desirable for the localizing beacon, since in coming in for a landing the presence of the courses at right angles to the runway might prove confusing.

The boundary beacon consists of a 50-watt transmitter feeding a loop-type antenna. Modulation of the radiated wave to the desired frequency, 1,000 cycles per second, is obtained by supplying the transmitting tube with a plate voltage of 1,000-cycle frequency. On the airplane, ear phones connected in series with the main course indicator are employed with a special filter circuit. The boundary line is defined by a zero signal zone, 2 or 3° wide. The pilot observes an increase in the marker beacon signal as he approaches the edge of the landing field, a decrease to zero as he passes over the boundary line, then an increasing signal as he comes within the landing-field area.

THE LANDING BEAM

On the airplane, the signal current in the output circuit of the special

Plaintiffs' Exhibit 6C.

U. S. DEPARTMENT OF COMMERCE
AERONAUTICS BRANCH

AIR COMMERCE BULLETIN

ISSUED SEMIMONTHLY

Vol. 2 Washington, December 1, 1930 No. 11

CONTENTS

- Program of national conference on uniform aeronautic regulatory laws announced.
- Automatic volume control for visual radio range beacons developed.
- Progress in scheduled air transportation marked during year.
- Air navigation directions of Bahama Islands.
- General aeronautic developments:
  - Estimate of aircraft production for January 1, to September 30, 1930.
  - Contracts totaling $288,209.42 awarded by Aeronautics Branch.
  - Estimate of gasoline and oil consumption by civil aircraft in first half of 1930.
  - More than 1,000,000 persons carried in flying operations of all kinds in first half of 1930.
  - Air navigation aids between San Francisco and Elko shown on chart.
  - Engines having approved-type certificates as of November 15, 1930.
- Notices to airmen and aircraft operators:
  - Airport and airway changes and warnings.
  - Airway progress.
  - New airway bulletins.
  - New aviation chart.
  - Air navigation charts revised.
  - Certified aeronautical lights.
  - Recent air markings.
  - Proposed airports.
  - Airports no longer proposed.
- Licenses, identifications, and approvals:
  - Summary.
  - New approved-type certificates.
  - New approved repair station certificates.
  - Revisions in approved type certificates.
  - Revision in list of approved school certificates.
  - Approvals without A. T. C.
  - United States air-transport routes.

PROGRAM OF NATIONAL CONFERENCE ON UNIFORM AERONAUTIC REGULATORY LAWS ANNOUNCED

The National Conference on Uniform Aeronautic Regulatory Laws, which will be held in Washington under the auspices of the Aeronautics Branch of the Department of Commerce December 16 and 17, will be opened Tuesday morning, December 16, by an address of welcome by Robert P. Lamont, Secretary of Commerce. Announcement of the conference was made in the Air Commerce Bulletin of November 15.

The governors of the 48 States, the Territories, and the Commissioners of the District of Columbia have been invited to send two delegates each to the conference. The aircraft industry will be represented by delegates designated by the Aeronautical Chamber of Commerce. Representatives will also be appointed by the Chamber of Commerce of the United States and the National Aeronautic Association.

The subjects to be discussed will include uniform basic regulatory State air law; adoption of Federal air-traffic rules by the States for purposes of local enforcement; methods of local enforcement; State enabling acts for airport acquisition and control and importance of uniform airport field rules. Clarence M. Young, Assistant Secretary of Commerce for Aeronautics, will preside at all of the sessions.

The program for the conference follows:

TUESDAY MORNING, DECEMBER 16

1. Address of welcome.—Robert P. Lamont, Secretary of Commerce.
2. Response on behalf of the States.—State Senator J. Griswold Webb, chairman of the New York State Aviation Commission.
3. Purpose of conference.—Clarence M. Young, Assistant Secretary of Commerce for Aeronautics.
4. Importance of uniform aeronautic regulatory laws to American commerce

and industry.—William Butterworth, president Chamber of Commerce of the United States.

5. Importance of uniform aeronautic regulatory laws to the aircraft industry.—Frederick B. Rentschler, president, Aeronautical Chamber of Commerce of America (Inc.).

6 Special problems in aeronautic legislation.—William P. MacCracken, jr., formerly Assistant Secretary of Commerce for Aeronautics.

7. Program of the National Aeronautic Association as related to uniformity in aeronautic legislation and regulation.—Senator Hiram Bingham, president, National Aeronautic Association.

TUESDAY AFTERNOON

Round-table discussion on foregoing subjects.

WEDNESDAY MORNING, DECEMBER 17

1. Aeronautic regulation and enforcement as viewed by the aircraft manufacturer and operator.—Lester D. Seymour, vice president and general manager National Air Transport.

2. Problems of local enforcement of uniform air-traffic rules.—Clarence M. Knox, commissioner of aviation, State of Connecticut.

3. Methods of local enforcement of uniform air-traffic rules.—John M. Vorys, director, Ohio State Bureau of Aeronautics.

4. Legal phases of local enforcement of uniform air-traffic rules.—George B. Logan, member, American Bar Association Committee on Aeronautics.

5. Importance of suitable airport enabling acts and uniform airport field rules.—Richard B. Barnitz, director of airports, City of Los Angeles, Calif

WEDNESDAY AFTERNOON

1. Round-table discussions on foregoing subjects.

2. Special problems facing the aircraft industry.—F. G. Coburn, president Aviation Corporation.

ADDITIONAL ACCEPTANCES

The Department of Commerce on November 17 had received notification of appointment of delegates, in addition to those listed in the Air Commerce Bulletin November 15, as follows:

Delaware: Gov. Douglas Buck, to be represented by Henry B. du Pont and Angus Echols, both of Wilmington.

Florida: Gov. Doyle E. Carlton, to be represented by Ed R. Bentley, of Lakeland, and Paul E. Grassfield, of Jacksonville.

Kansas: Gov. Clyde M. Reed, to be represented by Lloyd Stearman, of Wichita, and Ed Rooney, of Topeka.

Michigan: Gov. Fred W. Green, to be represented by W. B. Mayo, of Dearborn, and Walter E. Nicol, of Romulus.

New Mexico: Gov. R. C. Dillon, to be represented by J. O. Seth, member of the New Mexico Law Commission, of Santa Fe.

Ohio: Gov. Myers Y. Cooper, to be represented by John M. Vorys, director, Ohio State Bureau of Aeronautics, of Columbus, and Earle L. Johnson, member of the Ohio General Assembly, of Painesville.

Tennessee: Gov. Henry H. Horton, to be represented by R. S. Boutelle, State Highway Department, of Nashville, and L. W. Hughes, Porter Building, Memphis.

Utah: Gov. George H. Dern, to be represented by Harvey L. Finch, commissioner of parks and public property, and George F. McGonagle, member of the Public Utility Commission, both of Salt Lake City.

District of Columbia: L. H. Reichelderfer, president of the Board of Commissioners, to be represented by Maj. D. A. Davison, assistant engineer commissioner, and Lawrence E. Williams.

Porto Rico: Gov. Theodore Roosevelt, to be represented by Judge Felix Cordova Davila, Resident Commissioner.

The following have accepted and will designate two official representatives later: Maryland, Gov. Albert C. Ritchie; Virginia, Gov. John Garland Pollard; Alaska, Gov. George A. Parks.

AUTOMATIC VOLUME CONTROL FOR VISUAL RADIO RANGE BEACONS DEVELOPED

For some time there has been great need for a suitable device for automatically maintaining constant volume output from an aircraft receiving set under conditions of varying input voltages. In the course of a flight on an air route provided with radio range beacon facilities, the varying distance between the airplane and beacon station results in variations in the received signal intensity of the order of 5,000 to 1.

This variation is apt to prove troublesome, particularly when following the radiobeacon course within the last 10 to 15 miles of the beacon station, in the region where the beacon signal strength changes most rapidly. The rapid change of signal strength requires constant adjustment of the volume control by the pilot in order to keep the receiving set output signal from getting uncomfortably loud in the case of reception on the aural-type beacon or to keep the reed vibration amplitudes within proper bounds so that they may be compared in the case of reception on the visual-type beacon. Since one of the chief functions of the radio range beacon is to serve as a homing device, its use during the last 10 to 15 miles should be made as easy as possible.

To this end, the aeronautics research division of the Aeronautics Branch has developed an automatic volume control for use on receiving apparatus for the visual-type beacon, which relieves the pilot of volume control manipulation. This device has been in continuous use on the research division's experimental airplane for several months and has demonstrated its convenience and efficiency in several ways. A salient feature of the design of this device is that it may be readily adapted to existing commercial aircraft receiving sets. The theory of its operation together with the possibilities of its use are described herewith.

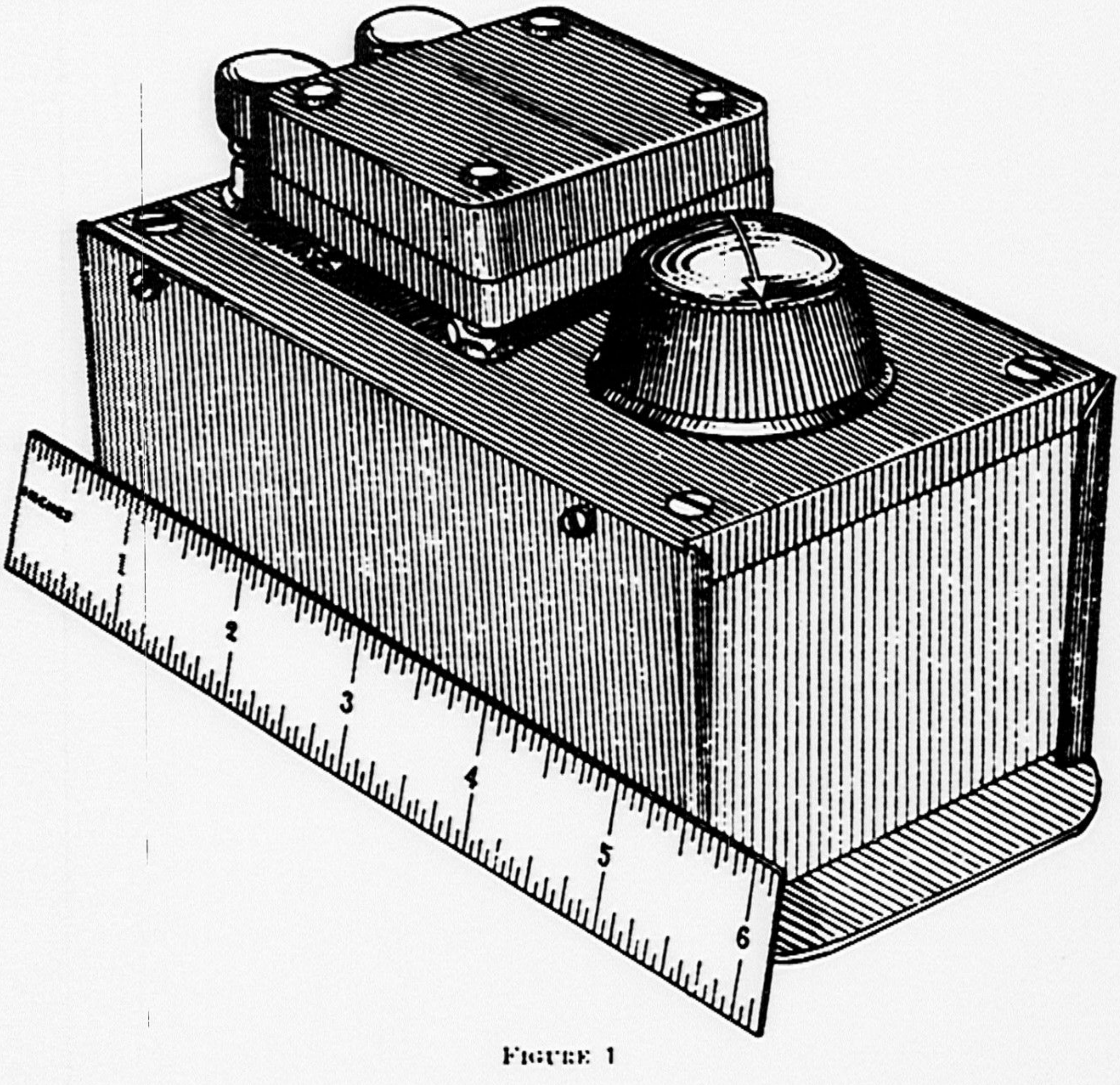


FIGURE 1

APPLICATION TO RECEIVING SET

The automatic volume-control unit consists of a copper oxide rectifier and simple filter circuit arrangement. A drawing of the complete unit is shown in Figure 1. The ease with which the automatic volume-control unit is applied to a particular type of receiving set depends upon the manner in which manual volume control is accomplished in that set. In all cases a portion of the receiving set output voltage which operates the reed indicator is applied to the input terminals of the copper oxide rectifier. The pulsating output voltage of this rectifier is then smoothed out by means of the filter circuit arrangement, the resultant direct voltage (of negative polarity) being used for effecting the automatic control.

In the first receiving set to which automatic volume control was applied, it was necessary to make a slight modification of the input circuits to the radio frequency amplifying tubes to permit the use of the negative controlling voltage from the output of the automatic volume-control unit as a biasing voltage on their grids. Fortunately, in later models of this type of receiving set, the manual volume control is carried out by means of an adjustable negative direct voltage on the grids of the radio frequency amplifying tubes. In this case the application of the negative controlling voltage on these grids is possible without modification of the set in any way.

The manner of operation of the automatic volume control is, then, as follows: Any increase in the voltage across the reed-indicator terminals, due to an increasing input voltage to the receiving set, is accompanied by an increase in the voltage applied to the copper oxide rectifier and consequently in an increasing negative direct voltage on the grids of the radio frequency amplifying tubes. This results in a decrease of the receiving set sensitivity, thereby tending to maintain substantially constant output voltage across the reed-indicator terminals. The reed-vibration amplitudes thus remain nearly constant regardless of the distance of the airplane from the radio range beacon station, without any necessity for manipulation on the part of the pilot.

In a second type of receiving set to which the research division has recently applied automatic volume-control operation, manual volume control is carried out by varying the direct positive voltage applied to the shield grids of the radio frequency amplifying tubes. In this case, in order that no modification of the receiving set may be required, the direct negative controlling voltage from the output of the automatic volume control unit is connected in opposition to the positive direct voltage on the shield grids.

MAINTENANCE OF VOLTAGE

Increasing input voltages to the receiving set which would tend to increase the output voltage across the reed indicator are thus accompanied by reduction in the net positive voltage applied to the shield grids of the radio frequency amplifying tubes and thereby by reduced receiving-set sensitivity. Substantially constant output voltage across the reed-indicator terminals is thus maintained.

With each method of automatic volume-control operation, the rectifier filter circuit arrangement is so designed that for very large input voltages to the receiving set sufficient alternating voltage passes through the filter (and is imposed on the radio frequency amplifying tubes) to cause modulation of the input signal. This is evidenced by a pulsation of the amplitude of vibration of the reeds about a mean value at a very low frequency. This pulsation may be made to begin at input voltages to the receiving set corresponding to those obtained at a distance of 1 to 2 miles from the beacon station. This phenomenon may then be utilized to give direct indication of approach to the beacon. The pulsation of the reeds beginning, say, at 2 miles from the beacon and growing progressively greater as the airplane approaches the beacon tower, warns the pilot of this approach and permits him to watch the reed indicator more closely for the zero-signal indication which occurs when passing directly over the beacon tower.

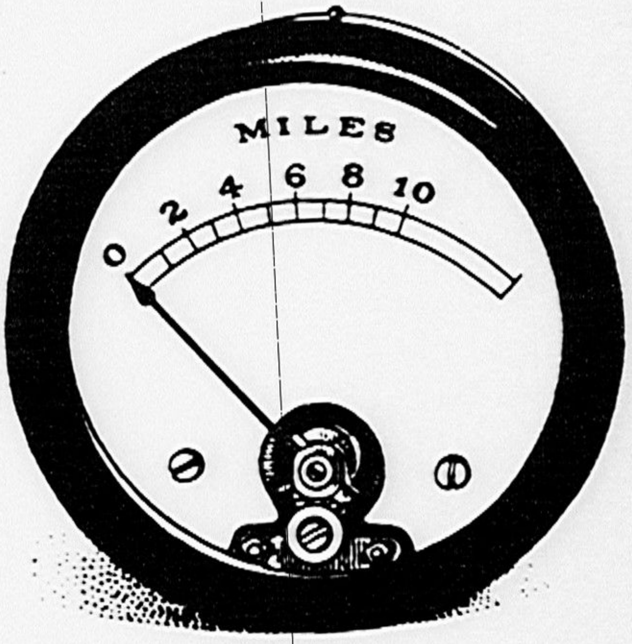


FIGURE 2

Automatic volume-control operation has proved particularly useful in connection with the use of the runway localizing beacon forming a part of the system of blind landing aids which the research division is developing. In connection with the automatic volume control it has been possible to employ a deflection instrument which serves as an approximate indicator of distance from the localizing beacon transmitter. This instrument is connected either in the plate circuit or shield grid circuit of the radio

frequency amplifying tubes of the receiving set and reads the direct current in the circuit in which it is connected. It will be noted that the automatic volume-control action is such as to reduce the deflection of this instrument for increasing input voltages to the receiving set; that is, as the airplane approaches the beacon transmitter. A drawing of the deflection instrument calibrated approximately in miles from the beacon transmitter is given in Figure 2.

AURAL OPERATION

So far the operation of the automatic volume-control device has been treated only in connection with its use on the visual-type radio range beacon. This device will not operate satisfactorily on speech or on the aural-type beacon. However, when radiotelephone and visual-type beacon signals are transmitted simultaneously (a development which is now in progress at College Park, Md.), automatic volume-control operation may be successfully employed. A special filter circuit arrangement is here employed to separate the reed and speech frequencies. The automatic volume-control device is connected so that it may be affected only by the reed signals. The receiving set sensitivity is thereby automatically controlled so as to maintain constant reed vibration amplitudes. The speech signals, which bear a definite average voltage ratio to the reed signals, will therefore also be kept at constant average value but are permitted to vary in instantaneous value to correspond to instantaneous changes in the speech modulation.

PROGRESS IN SCHEDULED AIR TRANSPORTATION MARKED DURING YEAR

The year's progress in civil aeronautics has been marked particularly by continued development of scheduled air transportation of mail, passengers, and express, according to the annual report of Clarence M. Young, Assistant Secretary of Commerce for Aeronautics, to the Secretary of Commerce.

The passenger air transport lines are constantly attracting that large group of people who could travel by air, but for one reason or other have elected to remain with surface transportation, the report states. Those air lines that render a service clearly advantageous in time over other means of travel or which advantageously augment surface transportation are doing a substantial business, and the tendency points to continued increase.

Although progress in the manufacture and sale of aircraft for miscellaneous use did not continue as rapidly in the last 6 or 8 months of the fiscal year ended June 30, 1930, as during the fore part of the year, this was not regarded as being necessarily discouraging.

"Manufacturers of aircraft," the report says, "who are just as skilled in the principles of business economics as they are in designing, constructing, and flying aircraft, are paying strict attention to the needs and desires of an intelligent and discriminating aircraft market. They are making every effort to design and produce aircraft which their experiences and studies have indicated are what the public wants. At the same time they are projecting plants continually on new developments, new designs, new features, in an effort to keep in the van of public desire."

Scheduled air transport operators flew 25.141.499 miles in the calendar year 1929, carried 173,405 passengers, 1.866 879 pounds of express, and 7.772.104 pounds of mail. They received payments for transportation of air mail totaling $17.042.520.71, according to the report.

DEVELOPMENT OF AIRWAYS

Under its program of airways development, the Aeronautics Branch during the last fiscal year lighted 3 321 miles of airways, established and lighted 58 intermediate landing fields, and installed and operated 218 standard revolving beacon lights for the guidance of airmen after dark, the report continues. Five thousand six hundred and fifty miles of airways were equipped with automatic telegraph-typewriter circuits which collect and disseminate weather information along the airways, and 13 radio broadcasting stations were placed in operation for the broadcast of this weather information to planes in flight at regular intervals both day and night. Two radio range beacons, which guide pilots along the airways by means of radio signals, also were placed in operation.

Feb. 5, 1935. G. HAGEN **1,990,072**

RADIO RECEIVER WITH AUTOMATIC VOLUME CONTROL SWITCH

Filed Dec. 30, 1932

Fig. 1

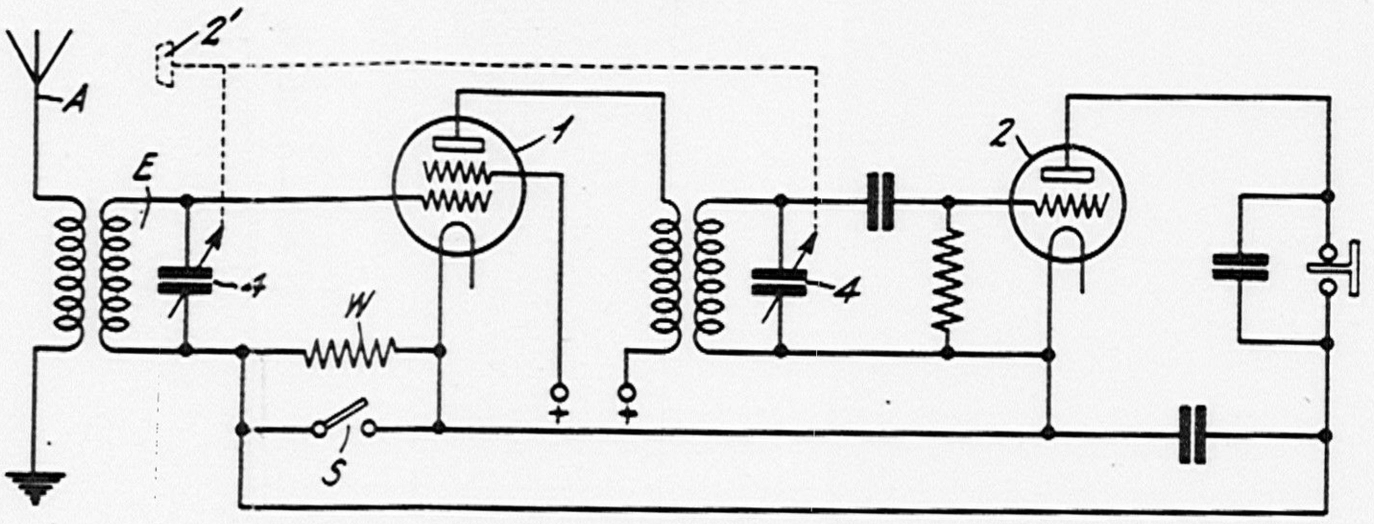
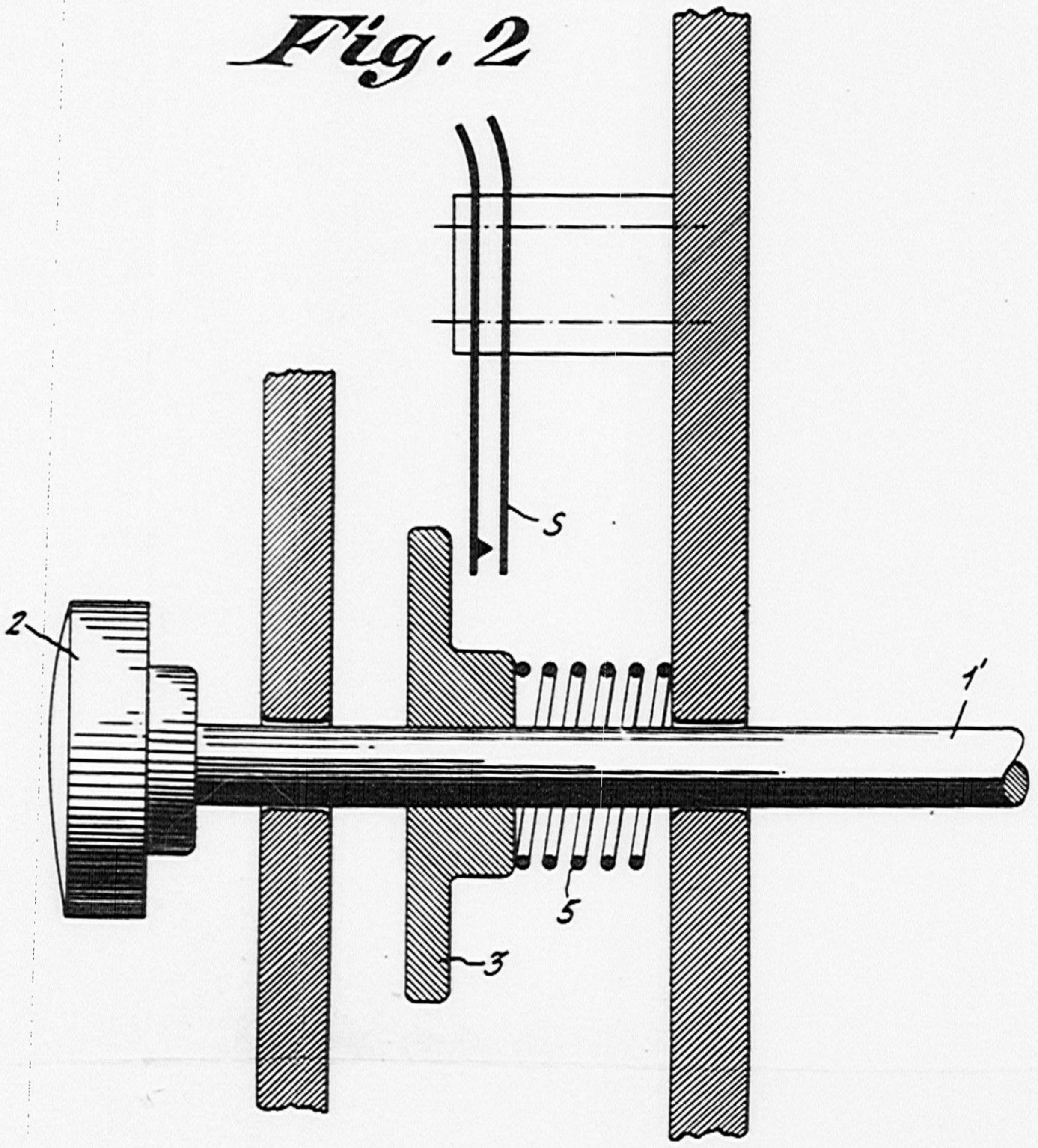


Fig. 2



INVENTOR
GERHARD HAGEN
BY H. G. Grover
ATTORNEY

Patented Feb. 5, 1935

1,990,072

UNITED STATES PATENT OFFICE

1,990,072

RADIO RECEIVER WITH AUTOMATIC VOLUME CONTROL SWITCH

Gerhard Hagen, Berlin, Germany, assignor to Telefunken Gesellschaft für Drahtlose Telegraphie m. b. H., Berlin, Germany, a corporation of Germany

Application December 30, 1932, Serial No. 649,453
In Germany January 22, 1932

7 Claims. (Cl. 250—20)

The invention is concerned with a radio receiver comprising means adapted to insure automatic volume control.

Radio receivers which are equipped with a device for automatic regulation of the volume or intensity of reproduction by a loud speaker, especially for the compensation of fading phenomena, involve the drawback that they are difficult to tune to the incoming waves. While in the case of an ordinary receiver set detuning in reference to the incoming waves manifests itself immediately by a marked reduction of the incoming volume, this condition is not quite so conspicuous and apparent in the case of receiver apparatus having automatic volume control means. Indeed, whatever loss or attenuation may be due to imperfect or improper tuning will be compensated by a corresponding increase in the gain.

In other words, imperfect tuning to the useful, or operating, wave will not manifest itself so much in a loss of reproducing volume as in an impairment of the quality of reproduction. The increase in gain, occasioned as a result of imperfect tuning of the set, also results in the fact that the ordinary background noise will be amplified much more markedly, whereby the desired reduction of background noise, usually insured by the use of highly selective tuning means, is lost.

According to this invention, proper tuning of such a receiver set, and thus the insurance of perfect quality of reproduction, is promoted by that circuit means are provided whereby AVC (automatic volume control hereinafter) may be transiently or temporarily rendered inoperative. The tuning of such a set is effected in this manner that first, with the automatic volume control device disconnected, the receiving set is tuned to the incoming wave. The incidentally occurring marked fluctuations in the volume constitute a criterion of the proper tuning.

After tuning has been effected, then the volume control is rendered operative, and in this manner a compensation of fading will be insured in the presence of invariable and optimum receiving conditions.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims, the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically one circuit organization whereby my invention may be carried into effect.

In the drawing,

Fig. 1 shows a receiver circuit including the invention,

Fig. 2 shows a tuning knob associated with the invention.

An embodiment of the basic idea of the invention is shown in the drawing in Fig. 1. A denotes the antenna, E is the input circuit of the receiver. The input tube 1 is here shown as of the screen grid type whose control circuit includes a resistance W traversed by the plate current of the detector tube 2. A switch S is furnished whereby the resistance W may be bridged and short-circuited.

One particular form of construction incorporating the basic idea of this invention is shown in Fig. 2 and consists in that the switch S is positively associated with the operating element of the tuning means. Thus, the tuning knob 2′ driving and controlling the tuning means 4 is made elastic. For operating the tuning means it must be subjected to pressure with the switch S being incidentally closed. When in its position of rest (inoperation), the control knob responding to the elastic force will keep the switch S in opened condition.

Fig. 2 shows an arrangement of this kind. 1′ denotes the condenser spindle on which is fitted the tuning knob 2′. Arranged on the spindle is the disk 3 which is pressed towards the left-hand side by the agency of a spring 5. If, then, when tuning the knob 2′ is pressed inwards, the switch S will be rendered operative by the said disk 3 while the pressure lasts. This closes the switch, and the automatic volume control path is short-circuited during tuning.

While I have indicated and described one system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What is claimed is:

1. In a radio receiver of the type including an automatic volume control arrangement for a tunable radio frequency amplifier and a tuning means for said amplifier, a switch means for rendering said volume control arrangement inoperative, and means mechanically associated with said tuning means for rendering said switch means inoperative upon actuation of said tuning means whereby said automatic volume control arrangement is operative solely upon adjust-

ment of said tuning means to a desired carrier frequency setting.

2. In a radio receiver, a high frequency amplifier, a tuning means therefor including an adjustable tuning shaft, an automatic volume control arrangement electrically associated with the input circuit of said amplifier, a switch for selectively short circuiting said automatic volume control arrangement, and means mounted upon said tuning shaft for closing said switch upon adjustment of said tuning shaft.

3. In a radio receiver, a high frequency amplifier, a tuning means therefor including an adjustable tuning shaft, an automatic volume control arrangement electrically associated with the input circuit of said amplifier, a switch for selectively short circuiting said automatic volume control arrangement, and means mounted upon said tuning shaft for closing said switch upon adjustment of said tuning shaft, and additional means for normally maintaining said last named means out of contact with said switch.

4. In combination in a radio receiver of the type including a signal amplifier, tuning means for the amplifier, a rectifier, a reproducer and automatic volume control means for regulating the sensitivity of said amplifier in a manner such that the amplifier is at maximum sensitivity when received signals are at a minimum amplitude, auxiliary means for selectively rendering the control means inoperative to regulate the amplifier, and said auxiliary means being operatively associated with the tuning means in such a manner that adjustment solely of the tuning means renders the auxiliary means operative to affect the volume control means whereby the latter is ineffective between signal carrier settings of the tuning means.

5. In combination in a radio receiver of the type including a signal amplifier, tuning means for the amplifier, a rectifier, a reproducer and automatic volume control means for regulating the sensitivity of said amplifier in a manner such that the amplifier is at maximum sensitivity when received signals are at a minimum amplitude, auxiliary switch means for selectively rendering the control means inoperative to regulate the amplifier, and said auxiliary means being operatively associated with the tuning means in such a manner that adjustment solely of the tuning means renders the auxiliary means operative to affect the volume control means whereby the latter is ineffective between signal carrier settings of the tuning means.

6. In combination in a radio receiver of the type including a signal amplifier, tuning means for the amplifier, a rectifier, a reproducer and automatic volume control means for regulating the sensitivity of said amplifier in a manner such that the amplifier is at maximum sensitivity when received signals are at a minimum amplitude, auxiliary means for selectively rendering the control means inoperative to regulate the amplifier, and said auxiliary means being operatively and mechanically associated with the tuning means in such a manner that adjustment solely of the tuning means renders the auxiliary means operative to affect the volume control means whereby the latter is ineffective between signal carrier settings of the tuning means.

7. In combination in a radio receiver of the type including a signal amplifier, tuning means for the amplifier, a rectifier, a reproducer and automatic volume control means for regulating the sensitivity of said amplifier in a manner such that the amplifier is at maximum sensitivity when received signals are at a minimum amplitude, auxiliary switch means for selectively rendering the control means inoperative to regulate the amplifier, and said auxiliary means being operatively and mechanically associated with the tuning means in such a manner that adjustment solely of the tuning means renders the auxiliary means operative to affect the volume control means whereby the latter is ineffective between signal carrier settings of the tuning means.

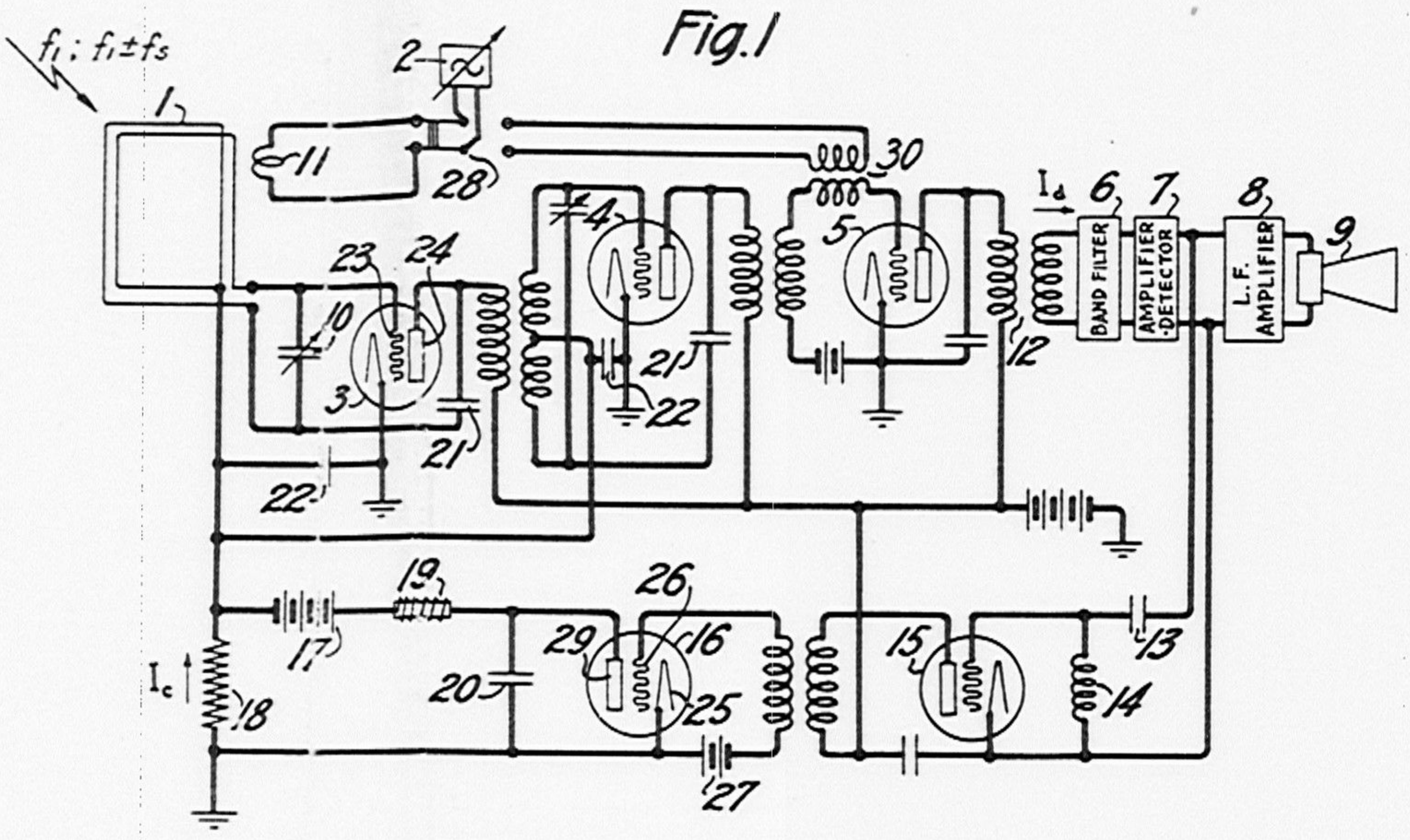
GERHARD HAGEN.

July 3, 1928. **H. T. FRIIS** **1,675,848**

TRANSMISSION REGULATION

Filed Nov. 29, 1924

Fig. 1



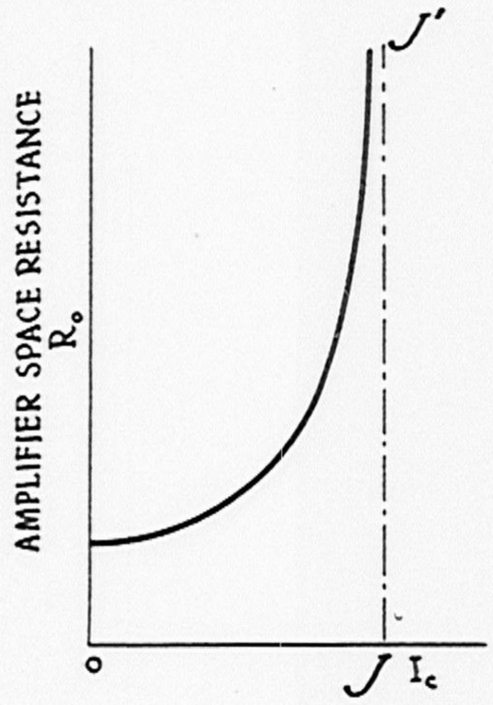
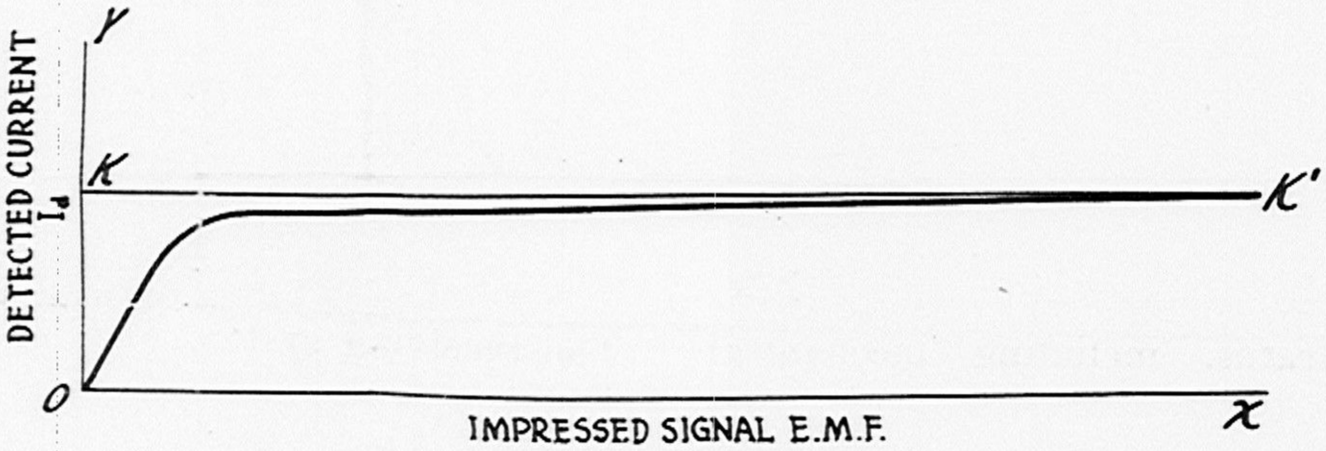


Fig. 2

Fig. 3



Inventor:
Harald T. Friis
by E. W. Adams Att'y.

Patented July 3, 1928. **1,675,848**

UNITED STATES PATENT OFFICE.

HARALD T. FRIIS, OF RED BANK, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

TRANSMISSION REGULATION.

Application filed November 29, 1924. Serial No. 752,891.

This invention relates to radio receiving systems and more particularly to methods of and means for controlling the intensity of received signals at a uniform level.

One object of the invention is to improve the constancy of the over-all transmission equivalent in radio communication systems.

It is well known that radio signaling waves are subject to extremely variable attenuation and that the strength of the received signals may vary so greatly as to make it difficult and even impossible at times to obtain satisfactory communication. These variations may be due to the regular changes between day and night conditions or they may be the much more rapid changes which are commonly known as "fading" effects. Slow changes of the former kind may be compensated by manual adjustment of the sensitivity of the receiving system, but compensation of the much more rapid fading effects requires some form of automatic adjustment.

To maintain a uniform transmission equivalent in a radio system it is necessary that any change in the attenuation of the medium be immediately offset by an opposite change in the gain characteristic of the receiving system. Methods of securing this result have been proposed by Espenschied and Bown in U. S. Patent No. 1,447,773, issued March 6, 1923, and by Affel in U. S. Patent No. 1,468,687, issued September 25, 1923.

The methods disclosed in these patents consist in radiating along with the signal wave a "pilot" wave of constant amplitude, and employing at the receiving station currents corresponding to this wave to control the sensitivity of the receiving system. The control apparatus, including mechanical elements, is so arranged that if the received pilot wave diminishes in intensity the sensitivity of the receiving system is increased by a corresponding amount and vice versa.

The pilot wave, being free from signal variations, is modified only by the attenuation of the transmission medium and therefore the control of the receiver gain is responsive only to changes in the attenuation of the medium. In most communication systems the signal is transmitted as a modulated carrier wave, which may be considered as a wave of single frequency and varying amplitude or alternatively as a group of waves including a constant wave of the carrier frequency and side waves representing the signal. It is therefore unnecessary to provide a special pilot wave as the carrier wave, when separated from the side waves, is satisfactory for the purpose. A transmitting system suitable for this method of transmission is described in U. S. Patent No. 1,442,147, January 16, 1923, to Heising.

By the present invention an improved means is provided for controlling the sensitivity of the receiving system in accordance with the intensity of the received carrier or pilot wave. The control is effected without the intervention of any mechanical device and may be made to respond accurately to and to compensate changes in the transmitting medium having periods of less than one fiftieth of a second.

In the detailed description which follows the invention will be described as applied to radio telephony for the reason that the need is greatest in that field. It is to be understood, however, that it may be applied equally well to any type of carrier wave system regardless of the nature of the medium of transmission.

Fig. 1 of the drawings shows a receiving system in which the invention is embodied;

Fig. 2 shows a special characteristic curve for an amplifier which is adapted to illustrate the operation of the invention; and

Fig. 3 is the operating characteristic curve of the receiving system of Fig. 1.

The receiving system of Fig. 1 is of the double detection or super-heterodyne type in which an intermediate frequency carrier wave is produced by demodulation of the incoming wave with an auxiliary wave locally generated. The incoming waves are received by the loop antenna 1 which may be tuned to resonance by means of condenser 10. The auxiliary wave is supplied from a local source 2 and is impressed upon the

135

high frequency circuit through a small loop 11 which is coupled to the receiving loop 1. Two stages of high frequency amplification are provided by the tandem connected space discharge amplifiers 3 and 4, both the incoming waves and the auxiliary waves being amplified thereby. The first stage of detection occurs in the space discharge demodulator 5 from the output of which the demodulation products are delivered through a transformer 12 to the band-pass filter 6.

The function of filter 6 is to separate out and transmit only the intermediate frequency waves corresponding to the difference between the incoming wave frequencies and the auxiliary wave frequency. It is preferable that the intermediate frequency waves should occupy a band centered in the neighborhood of 50,000 cycles per second, the width of the band being made sufficient to include the intermediate frequency carrier and all side frequencies necessary for the proper reproduction of the signal. The filter may be constructed in accordance with the methods and formulæ disclosed in U. S. Patent No. 1,227,113, issued May 22, 1917, to G. A. Campbell.

The selected intermediate frequency band is amplified in the amplifier-detector 7, in which the final step of detection to produce the low frequency signal currents also takes place. The low frequency currents are delivered to an amplifier 8 and the amplified current is supplied to the signal reproducer 9, which is illustrated as a loud speaking telephone.

The amplifier-detector 7 and the amplifier 8 are indicated only in conventional form, the particular type and arrangement used being unimportant, since any well known devices adapted to perform the desired functions may be used.

The local auxiliary wave source 2 should be adjustable so that the frequency of the intermediate carrier wave and the associated side frequencies may be within the range selected by the filter 6. A suitable form of auxiliary source is the space discharge oscillator disclosed in U. S. Patent No. 1,356,763, issued October 26, 1920 to R. V. L. Hartley.

The control current by which the sensitivity of the receiver is regulated is selected from the output of the amplifier-detector 7 by the resonant circuit 13, 14, connected in shunt to its output circuit, which is tuned to the frequency of the intermediate carrier wave. Its voltage after being amplified in the space discharge amplifier 15 is impressed upon the space discharge detector 16 in the output of which it produces a steady direct current. The control electrode 26 of the detector is so polarized by the battery 27 that little or no space current flows normally; consequently in accordance with the well known characteristics of space discharge detectors, an alternating E. M. F. impressed upon the control electrode produces a direct current in the space path which increases as the impressed E. M. F. increases.

The output circuit of the detector 16 includes the space discharge path between the anode 29 and the cathode 25, a separate space current source 17 and a fixed resistance 18. The cathode and one terminal of the resistance 18 are connected together at ground potential. Choke coil 19 and condenser 20 serve to prevent the flow in resistance 18 of any alternating current corresponding to the impressed intermediate frequency wave.

For reasons that will be explained later, the high frequency amplifiers 3 and 4 are provided with balancing capacities 21 to neutralize the coupling between the output and the input circuits of the amplifiers due to the internal electrode capacities.

In the first high frequency amplifier, the cathode is connected through a relatively large capacity 22 to the mid-point of the receiving loop, the potentials of the end terminals of which are therefore balanced with respect to the cathode and are of opposite sign. One terminal of the loop is connected to the input or control electrode 23 of the amplifier and the other is connected through the balancing condenser 21 to the anode 24. The capacity of the condenser 21 is substantially equal to the direct capacity between the electrodes 23 and 24. By this means, any current that might be transmitted directly from the input to the output of the amplifier through the electrode capacity is neutralized by an equal and opposite current transmitted through the balancing condenser.

The circuit of the second stage is similar and operates in a similar manner. The system of neutralization described has been disclosed in U. S. Patent No. 1,334,118, issued March 16, 1920 to C. W. Rice.

The control of the sensitivity of the system is secured by causing the rectified output current of the detector 16 to modify the control electrode potentials of the amplifiers 3 and 4. The cathodes of these amplifiers are connected to ground, and the control electrodes are connected to the ungrounded terminal of resistance 18, whereby they are caused to assume the potential of this point. This potential is determined by the current flowing in the resistance.

As current can flow only in the direction from ground to the anode of the detector 16, the fall of potential across the resistance 18 is such as to impress a negative potential upon the amplifier control electrodes. An increase of the current in the resistances 18 will increase the negative potential applied to the control electrodes of the amplifier and in consequence will reduce the amplifier space currents. This is equivalent to increasing the internal resistance of the amplifiers and is effectual in reducing their over-all amplification. It follows then that an increase in the intensity of the incoming wave, by producing an intermediate frequency carrier wave of larger amplitude, causes an increased current to flow in the resistance 18, and thereby reduces the sensitivity of the receiving system.

The relationship between the space path impedances of the amplifiers 3 and 4 and the polarizing potentials of their control electrodes is shown qualitatively by the curve in Fig. 2. The ordinates are proportional to the space path impedance; the abscissæ are proportional to the steady current I_c flowing in the resistance 18, and therefore to the polarizing potentials applied to the control electrodes of the amplifier. The vertical dotted line JJ′ corresponds to the potential that is just sufficient to reduce the space current to zero, the space path impedance becoming infinite under this condition.

The detected current I_c cannot exceed the value corresponding to the abscissa OJ; since it requires for its production that some part of the incoming wave be repeated by the amplifiers and this cannot take place if the amplifiers are blocked. A continually increasing intensity of the incoming wave may cause the detected current to approach indefinitely close to the limiting value, but it can never attain such a value that the amplification of waves by the amplifier is actually stopped. The detected current will therefore be substantially constant for all intensities of the incoming wave greater than some low value depending on the initial sensitivity of the system. Since the detected current remains constant, it follows that the intermediate frequency carrier wave from which it is produced must also remain constant.

The relationship between the current intensity of the intermediate frequency carrier wave and the E. M. F. of the incoming signal carrier wave is shown by the curve of Fig. 3. The abscissæ are proportional to the E. M. F. of the incoming carrier wave measured at the input terminals of the amplifier 3, and the ordinates are proportional to the current intensity denoted by I_d, of the intermediate frequency carrier wave at the point where it enters the band filter.

The horizontal line K, K′ represents the limiting value that the current I_d may approach, but which it cannot equal or exceed. The ordinate OK is proportional to the intensity that produces the limiting value OJ in Fig. 2, of the control current I_c. The slope of the curve at the origin of the coordinates is proportional to the initial sensitivity of the system; namely the sensitivity that would be obtained if the control system were made inoperative, or the sensitivity that is obtained for such low intensities of the incoming wave that the effect of the control is negligible. Obviously, as the initial sensitivity of the system is increased, the control system will be operative to effect regulation at lower and lower intensities of the incoming waves.

The uniformity of the intermediate frequency carrier wave resulting from this method of control, corresponds to transmission through a medium of constant attenuation; the sound waves of the impressed message are reproduced with a strength that faithfully follows their original intensity regardless of the variations to which radio waves are subject in the medium.

It should be noted that the control affects only those waves that are repeated by the controlled amplifiers in the normal manner; it is not effective upon such portion of the waves that may be transmitted directly through the capacities of the amplifier electrodes.

Strong incoming waves might, under certain conditions, cause sufficient current to be transmitted through the amplified capacities to cause the control current I_c to reach and exceed the limiting value at which the amplifiers become blocked. Stronger wave intensities would then be uncontrolled, the amplifiers operating merely as fixed capacity networks to produce a fixed attenuation of the waves. By neutralizing the coupling between the input and the output circuits of the controlled amplifiers in the manner hereinbefore described, the direct transmission of the incoming wave is largely prevented and the range of intensities that can be controlled is greatly increased.

The use of two controlled amplifiers in tandem further increases the range that can be controlled by increasing the attenuation to which directly transmitted waves are subjected. Satisfactory control may, however, be obtained over a wide range of intensities using only one controlled amplifier.

An additional feature of the system described above that tends to increase the operating range of intensities, is the arrangement whereby the auxiliary wave from the local source is subjected to the action of the controlled amplifiers. As the intensity of the incoming wave increases and, through the action of the control circuit, reduces the effective amplification of the amplifiers, the strength of the auxiliary wave E. M. F. impressed upon the detector 5 is reduced.

Hence the intermediate frequency carrier approaches the limiting value at a slower rate than it would if the auxiliary wave were not controlled, and further, the component of the intermediate carrier due to the incoming wave is very small. Both of these factors are effective in extending the operating range.

With this arrangement, the demodulation of strong incoming waves in the detector 5 takes place with a considerably weakened auxiliary wave. Such a condition may give rise to a larger number of harmonics and other undesired modulation products, but these are suppressed by the band filter 6.

An alternative arrangement of the circuit may be used in which the auxiliary wave is impressed directly upon the demodulator 5 and is therefore not subject to the action of the controlled amplifiers. To permit the use of this arrangement, a switch 28 is provided by which the local source 2 may be connected to a coupling transformer 30, the secondary of which is connected in series with the input circuit of the demodulator. With this arrangement, constant conditions in the demodulator are obtained since the incoming wave is maintained at substantially constant intensity by the control current.

The response of the control to changes in the strength of the incoming wave is exceedingly rapid; that it is not instantaneous is due only to the presence of the condensers 22 and 20 which are connected in parallel with the resistance 18. The condensers 22 are inserted to provide a low impedance connection for the high frequency waves between the cathodes and the tuning coils in the amplifier input circuits. The condenser 20 is provided to absorb the alternating current in the output of the detector 16. They are effective in reducing the rapidity of response because they require a certain small time to charge or discharge when the applied potential is changed. It is found that the total capacity may be as great as 1 mfd. without increasing the response time above one-fiftieth of a second.

In experimental tests with a system of the type described but having only one controlled amplifier, received signals have been maintained constant in strength within 10% while the impressed wave intensities varied from a minimum to a maximum value one thousand times greater.

The operation of the invention has been described in connection with a double detection system, but it is obvious that the principles involved may be applied to the control of receiving systems in which no auxiliary wave is used and which employ only one demodulation of the incoming waves. Instead of an intermediate frequency carrier wave, the carrier component of the incoming waves would be selected to produce the control current, the selection, as in the system described, being made after the wave has passed through the controlled amplifier. The use of the double detection system, however, by establishing an intermediate carrier wave of relatively low frequency, makes it possible to separate the carrier more completely from its accompanying side frequencies and thereby to secure more exact regulation.

What is claimed is:

1. In a wave receiving system of the type in which an incoming carrier wave is demodulated with a locally generated heterodyne wave to produce a beat wave of a different frequency, a high frequency amplifier adapted to amplify both the incoming carrier wave and the heterodyne wave before demodulation, demodulating means, a rectifier adapted to produce a direct current from the beat wave, and means for controlling the efficiency of said amplifier in accordance with the strength of the rectified current whereby the intensity of the heterodyne wave applied to said demodulating means is diminished as the intensity of the incoming wave increases.

2. In a wave receiving system of the type in which an incoming carrier wave is demodulated with a locally generated heterodyne wave to produce a beat wave of a different frequency, means comprising a three electrode space discharge amplifier for amplifying both the incoming wave and the heterodyne wave before demodulation, demodulating means adapted to receive the amplified waves from said amplifier, a rectifying device for rectifying the beat waves produced by said demodulator and means for impressing the potential of the rectified current upon the control electrode of said amplifier, whereby the resistance of the space discharge path is increased in accordance with the intensity of the incoming wave.

3. In a heterodyne receiving system in which a space discharge amplifier is adapted to amplify the incoming waves and the heterodyne waves before detection, the method of controlling the sensitivity which comprises rectifying the waves of the beat frequency, and applying the rectified waves to reduce the efficiency of amplification of the incoming and the heterodyne waves.

4. In a heterodyne receiving system, a space discharge amplifier adapted to amplify the incoming waves and the heterodyne waves before detection, means for rectifying the waves of a beat frequency produced by detection and means for impressing the direct current potential of the rectified waves upon said amplifier to reduce its efficiency.

5. In a heterodyne receiving system, a method of controlling the volume of the detected signals which comprises simultaneously amplifying the incoming wave and the

heterodyne wave, and controlling the degree of amplification in an inverse manner as the amplitude of the received wave varies.

6. In a heterodyne receiving system, the method of controlling the volume of the detected signals which comprises amplifying the heterodyne wave prior to the step of detection, and varying the degree of amplification in an opposite sense to and in synchronism with variations of the intensity of the received wave.

In witness whereof, I hereunto subscribe my name this 28th day of November, A. D. 1924.

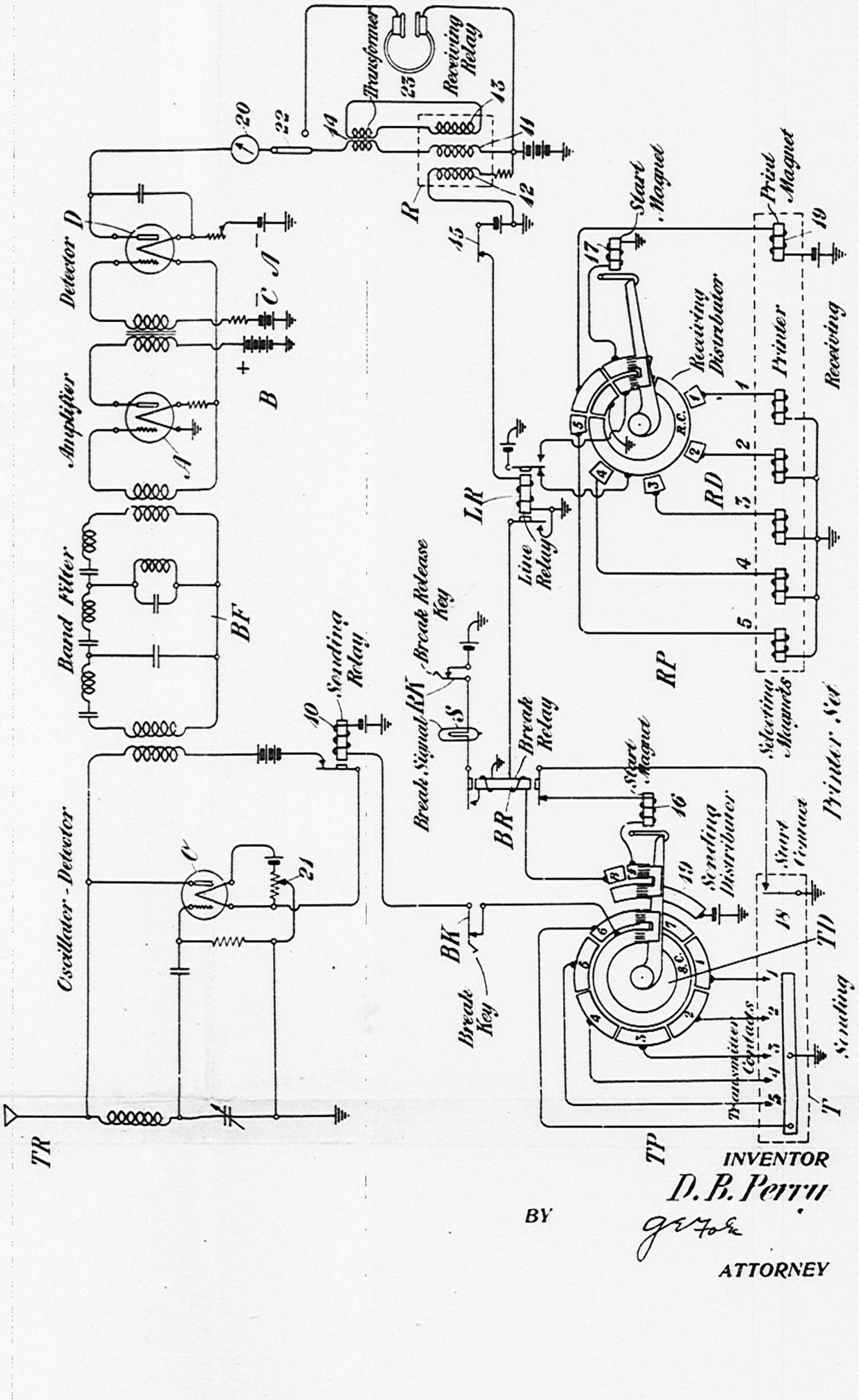
HARALD T. FRIIS.

May 5, 1925. 1,536,130

D. B. PERRY

OPERATION OF PRINTING APPARATUS BY RADIO

Filed March 29, 1924



INVENTOR

D. B. Perry

BY

ATTORNEY

Patented May 5, 1925. **1,536,130**

UNITED STATES PATENT OFFICE.

DONALD B. PERRY, OF YONKERS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

OPERATION OF PRINTING APPARATUS BY RADIO.

Application filed March 29, 1924. Serial No. 702,877.

To all whom it may concern:

Be it known that I, Donald B. Perry, residing at Yonkers, in the county of Westchester and State of New York, have invented certain Improvements in Operation of Printing Apparatus by Radio, of which the following is a specification.

This invention relates to radio signaling and more particularly to the transmission of printing telegraph messages by means of radio.

Printer intercommunication by radio on the half-duplex basis presents certain difficulties, particularly in the matter of breaking by a receiving operator to obtain control of the circuit for sending. In ordinary radio telegraph service, except where special provision is made for duplex operation, it is necessary for a station that is receiving to wait until the sending operator stops and listens before it may send. This method, if applied to printer service, will result in unsatisfactory service and no break feature.

It is one of the purposes of the present invention to connect a combination radio transmitter and receiver to a printer circuit in such a manner as to permit of an instantaneous break. This result may be accomplished by arranging two intercommunicating stations so that normally each station will send out a different wave length. At the sending station the wave length transmitted will have impressed thereon code combinations set up by the transmitting apparatus of a printing telegraph set. At both the transmitting and receiving stations a beat frequency may be obtained corresponding to the difference between the two radiated wave lengths, and upon this beat frequency the code combinations will be superposed. At each station the beat frequency will be selected and the code combinations will be detected therefrom to operate the receiving printer.

In a system such as above outlined, the receiving station will be radiating a continuous wave. By merely interrupting the continuous wave emitted from the receiving station the receiving operator may break the circuit, for the beat frequency will no longer be present and consequently the code combination sent out from the transmitting station will not be impressed upon the final detector at either the transmitting or receiving station. The sending operator will no longer receive his own copy and the printer circuit may be arranged in a well known manner so that under these conditions a break relay will be operated to stop the transmitter and give an audible or visual signal.

Further details and object of the invention will be clear from the following description when read in connection with the accompanying drawing, the figure of which illustrates a preferred embodiment of the invention.

Referring to the drawing, TR designates a radio antenna with which is associated a circuit of the vacuum tube O, arranged to generate and transmit from the antenna oscillations of a wave length differing from those radiated from a distant station by a definite beat frequency. The circuit of the vacuum tube O is controlled by the sending relay 10, which is associated with the transmitting printer TP, the circuit being normally closed when the transmitter TP is not actuated. Code combinations set up by the transmitter TP cause the sending relay 10 to successively interrupt the plate circuit of the vacuum tube O to impress the code combinations upon the wave length transmitted.

The vacuum tube oscillator O also functions as a detector to detect the beat note due to interaction of the wave length radiated from a distant station and the wave length radiated from the station under consideration. When code combinations are impressed upon either one of the wave lengths the beat frequency detected by the vacuum tube O will be interrupted in accordance with the code combination. A band filter BF, of a well known type, is associated with the plate circuit of the vacuum tube O to select the beat note carrying the code combination and impress it upon a suitable vacuum tube amplifier A. A vacuum tube detector D, of a well known type, is associated with the output circuit of the amplifier and functions to detect from the beat note the code combination which is impressed upon one or the other of the radio frequencies, depending upon whether the station illustrated is transmitting or whether the distant station is transmitting.

A receiving relay R is provided, said receiving relay having three windings. One of the outer ring of the distributor and returns to its normal position the closed circuit impulse transmitted to the sending relay 10 will be ineffective to transmit a closed circuit impulse to the line relay LR by reason of the absence of the beat note. As a consequence, a circuit will be completed from ground, over the left-hand back contact of the line relay LR, through the lower winding of the break relay BR, over the break segment B, brush and segment 19 of the distributor TD to battery. A momentary circuit is thus closed through the lower winding of the break relay as the brush arm passes over the break segment B so that the break relay BR is energized. A circuit is completed by the break relay through its locking winding over its upper front contact in series with the break signal S. At its lower armature the break relay BR holds open the circuit of the start magnet 16 and when the brush arm 19 comes to rest the brush arm can no longer be released in response to the closing of the start contact 18 as the sender T is further operated.

Upon observing the signal lamp S the operator at the station illustrated (which, as described, was sending) will open the release key RK, thereby unlocking the break relay BR. The operator also ceases to transmit by means of the transmitter T as soon as the break signal is observed, and as the circuit is now in its normal position the operator at the distant station may begin to transmit signals in the opposite direction. The transmission of signals from the distant station after the breaking operation will be obvious without further description as the circuit at the distant station is identical in all respects with that illustrated.

To aid in properly tuning the variable condenser in the circuit of the antenna TR, an ammeter 20 is shown connected in circuit with the operating winding of the receiving relay R. A change in the adjustment of the tuning condenser will vary the frequency of the beat note, assuming that the distant station is emitting a constant frequency. The maximum ammeter reading will indicate the beat note best transmitted through the band filter and the optimum setting of the variable condenser.

The system may be expanded to give intercommunication between more than two stations. In this case, each station will normally have assigned to it a "stand-by" wave length which it emits when not signaling. The stand-by wave length for each station will, of course, be different. When any particular station desires to signal another station the operator will adjust the antenna capacity to tune the output of the oscillator O to a frequency near that emitted by the desired station, thereby producing a beat note, which will be passed through the filter BF. The amplitude of the wave radiated should be reduced while tuning in in order to prevent interference in case the desired station is in communication with some other station. For this purpose, the grid connection of the oscillator may be varied, by means of the adjustable resistance 21, to increase the negative potential in the grid until the amplitude of the oscillations radiated is so small as not to cause interference with the distant station. The operator, while tuning, will throw the switch 22 to substitute a telephone receiver 23 for the receiving relay R. This is done for the reason that the operator will determine whether or not the desired station is signaling by receiving the signals transmitted from the distant intercommunicating stations and these signals will be so weak, because of the reduced amplitude of the frequency emitted by the station which is tuning in, that they will not operate the receiving relay. They may be readily heard in the receiver 23, however, so that the operator will know that the desired station is busy.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a radio signaling system, a plurality of intercommunicating stations, each station emitting waves of a different frequency, means at each station for producing a beat frequency from the two waves, means at each station for superposing telegraph signals on the wave emitted by that station whereby similar signals are superposed upon the beat frequency produced at each station, means whereby the wave which is emitted from the station which is receiving may be interrupted when the receiving operator desires to break in, thereby causing the beat frequency to cease, and means at the station which is sending responsive to the interruption of the beat frequency to operate a break signal at said station.

2. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency between the wave emitted and the wave received, means at each station to vary the wave emitted from that station in accordance with signal impulses, thereby producing a corresponding variation in the beat frequency produced at each station, means to detect signals from the beat frequency at each station, and means at the station which is receiving signals for interrupting the wave emitted from that station when it is desired to break in, thereby interrupting the beat frequency at each sta-

tion, and means at the station which is sending responsive to the interruption of the beat frequency to actuate a signal to indicate the break.

3. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted with the wave received, an automatic signal transmitter at each station, means controlled by said automatic signal transmitter to impress corresponding signal variations upon the wave emitted from that station, thereby producing similar signal variations upon the beat frequency at each station, means to detect the transmitted signals produced by the automatic signal transmitter from the beat frequency at each station, means at the station which is receiving for interrupting the wave emitted therefrom when it is desired to break, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the sending station to stop said automatic signal transmitter.

4. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted with the wave received, an automatic signal transmitter at each station, means controlled by said automatic signal transmitter to impress corresponding signal variations upon the wave emitted from that station, thereby producing similar signal variations upon the beat frequency at each station, means to detect the transmitted signals produced by the automatic signal transmitter from the beat frequency at each station, means at the station which is receiving for interrupting the wave emitted therefrom when it is desired to break, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the sending station to stop said automatic signal transmitter and actuate a signal to indicate the break.

5. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means to produce a beat frequency at each station by the interaction of the wave emitted with the wave received thereat, a printing telegraph transmitter at each station, means controlled by said transmitter at a station which is signaling for impressing code impulses upon the wave emitted from that station, thereby causing similar code impulses to be superposed upon the beat frequencies produced at both stations, means to detect said code impulses from the beat frequency at each station, a receiving printer at each station responsive to the detected code impulses to print a character corresponding to each code combination, means at the station which is receiving for interrupting the wave emitted from that station when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the station which is sending to stop said printing telegraph transmitter.

6. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means to produce a beat frequency at each station by the interaction of the wave emitted with the wave received thereat, a printing telegraph transmitter at each station, means controlled by said transmitter at a station which is signaling for impressing code impulses upon the wave emitted from that station, thereby causing similar code impulses to be superposed upon the beat frequency produced at each station, means to detect said code impulses from the beat frequency at each station, a receiving printer at each station responsive to the detected code impulses to print a character corresponding to each code combination, means at the station which is receiving for interrupting the wave emitted from that station when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations, and means responsive to the interruption of the beat frequency at the station which is sending to stop said printing telegraph transmitter and actuate a signal to indicate the break.

7. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted from that station with the wave being received thereat, a printing telegraph transmitter at each station for setting up code combinations, a distributor associated with each transmitter for successively impressing the impulses of the code combination upon the wave emitted from the corresponding station, thereby causing similar code combinations to be impressed upon the beat frequency produced at both stations, means at each station for detecting from the beat frequency the code combinations impressed thereon, a receiving printer at each station, a distributor associated with each receiving printer for impressing upon the elements of the printer the impulses of the detected code combination, means at the station which is receiving signals for interrupting the wave emitted therefrom when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations, and means responsive to the interrup-

tion of the beat frequency at the station which is sending to stop the distributor associated with the transmitter thereat.

8. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave having a different frequency, means at each station to produce a beat frequency by the interaction of the wave emitted from that station with the wave being received thereat, a printing telegraph transmitter at each station for setting up code combinations, a distributor associated with each transmitter for successively impressing the impulses of the code combination upon the wave emitted from the corresponding station, thereby causing similar code combinations to be impressed upon the beat frequency produced at each station, means at each station for detecting from the beat frequency the code combination upon the wave emitted from the corresponding station, thereby causing similar code combinations to be impressed upon the beat frequency produced at both stations, means at each station for detecting from the beat frequency the code combinations impressed thereon, a receiving printer at each station, a distributor associated with each receiving printer for impressing upon the elements of the printer the impulses of the detected code combination, means at the station which is receiving signals for interrupting the wave emitted therefrom when it is desired to transmit a break signal, thereby interrupting the beat frequency at each station, and means responsive to the interruption of the beat frequency at the station which is sending to stop the distributor associated with the transmitter thereat and to actuate a special signal to indicate the break.

9. In a radio signaling system, a plurality of intercommunicating stations, each station emitting a wave having a different frequency, means to produce a beat frequency at each station by the interaction of the wave emitted with the wave received thereat, a printing telegraph transmitter at each station, means controlled at said transmitter at the station which is signaling for impressing code impulses upon the wave emitted from that station, thereby causing similar code impulses to be superposed on the beat frequencies produced at both stations, means to detect said code impulses from the beat frequency at each station, a receiving printer at each station responsive to the detected code impulses to print a character corresponding to each code combination, means at the station which is receiving for interrupting the wave emitted from that station when it is desired to transmit a break signal, thereby interrupting the beat frequency at both stations so that the receiving printer at the transmitting station will not record the signals transmitted.

10. In a radio signaling system, a plurality of intercommunicating stations, each emitting a wave of a different frequency, means at each station to produce a beat frequency between the wave emitted and the wave received, means at each station to vary the wave emitted from that station in accordance with said signaling impulses, thereby producing a corresponding variation in the beat frequency produced at each station, means to select the beat frequency at each station, means to detect signals from the beat frequency at each station, and means at the station which is receiving signals for interrupting the wave emitted from that station when it is desired to break in, thereby interrupting the beat frequency at each station and preventing further operation of the detecting means.

In testimony whereof, I have signed my name to this specification this 26th day of March, 1924.

DONALD B. PERRY.

368 DEFENDANT'S EXHIBIT F.

United States Patent Office,
Washington.

B-3183.1 July 31, 1931.

Interference No. 60,839.

SIMONDS

vs.

WHEELER.

Limit of Appeal Aug. 20, 1931.

Motion to Disolve Motions to Amend.

This case is before the examiner of interferences upon a motion to dissolve brought by the party Simonds and upon two motions to amend brought by the party Wheeler.

Simonds has moved to dissolve on the ground that the counts now in issue are unpatentable over the prior art. In substantiation of his motion he calls attention to the patent to Friis, 1,675,848, the patent to Perry, 1,536,130, and a publication, "The Proceedings of the Institute of Radio Engineers", of 1923, Volume II, pages 115 to 152.

The invention involved in the present controversy has to do with constant volume radio receiving sets and a means for visually indicating the correct adjustment of the tuning of the set. Since the operation of a constant volume radio receiver tends to increase the limits of the dial movement between which the signal intensity remains substantially constant it becomes necessary to provide some means other than the audible indication produced by the radio 369 loud speaker for the purpose of indicating when the tuning adjustment of the set is such as to produce exact resonance with the incoming signal.

The party Simonds contends that no invention would be involved in applying to the constant volume radio receiver as shown in the Friis patent a visual indicator for the indication of resonance such as is shown in the Perry patent or in the publication cited.

In the specification of the Perry patent, page 4, lines 41 *et sequa*, the following statement appears:

> "To aid in properly tuning the variable condenser in the circuit of the antenna TR, an ammeter 20 is shown connected in circuit with the operating winding of the receiving relay R. A change in the adjustment of the tuning condenser will vary the frequency of the beat note, assuming that the distant station is emitting a constant frequency. The maximum ammeter reading will indicate the beat note best transmitted through the band filter and the optimum setting of the variable condenser."

Thus the Perry patent clearly teaches that a visual device may be used to indicate the correct tuning of the receiving apparatus.

In the publication cited, beginning at page 131, an explanation of the operation of the apparatus is given, and reads:

> "The operation of the set is as follows: The desired signal is picked up by the loop and receiving set and brought to a volume which gives a satisfactory reading on the
> 370 indicating instrument. By means of the fine adjustment condensers, and by watching the indicating instrument, the loop is tuned to exact resonance and the beating oscillator is set to place the intermediate frequency in exact resonance with the 45,000 cycle selective circuit of the amplifier."

Both the Perry patent and the publication teach that a visual indicator may be relied upon and utilized for the purpose of tuning the radio receiving apparatus to exact resonance with the incoming signal wave. The use of this expedient wherever it is desired to accomplish only that function is not believed to involve invention.

An examination of the Friis patent immediately discloses the need for a device which will show that the tuning condenser 10 is properly adjusted and in exact resonance with the incoming signal wave. The problem and its solution are apparent from the art. No invention is believed to be involved to utilize the indicating instruments as shown in the Perry patent or in the publication cited in the circuits shown in the Friis patent.

Simonds' motion to dissolve is granted.

The party Wheeler, in two separate motions, has moved to amend the issue and for this purpose has submitted proposed counts 57 through 62. The party Simonds has opposed this motion to amend the issue on the ground that the counts are unpatentable over the prior art. It was admitted by counsel for both parties at the hearing that
371 the proposed counts are properly applicable to the
devices shown by both parties.

Proposed counts 54 through 62 are believed to be unpatentable over the same references as were cited in the Simonds motion to dissolve and for the same reasons as therein stated. No further discussion of this matter is believed to be necessary. It may be noted, however, that count 62, in addition to being unpatentable over the prior art, is unpatentable for the reason that it is indefinite. The count includes the term "gain" which is of uncertain meaning as used in the count. If the term "gain" is taken to mean "amplification", the count is unpatentable over the prior art as cited against the proposed counts.

Proposed counts 58, 59 and 60 are not believed to be patentably distinct from count 1 now in issue. These counts differ from count 1 only in words and not in structure. Proposed count 55 is not believed to be patentably distinct from count 3 now in issue. The remaining proposed counts are believed to be patentably distinct from each other and from the counts now in issue.

Wheeler's motion to amend is accordingly denied for the reason that the proposed counts are unpatentable over the prior art.

Limit of appeal: August 20, 1931.

(S.) J. P. DISNEY,
Examiner of Interferences. Room 262.

372 DEFENDANT'S EXHIBIT G.

U. S. Patent Office. Board of Appeals. Feb. 26, 1932. Mailed.

Appeal No. 3901. REH.
January 25, 1932.
B-3183.1.

In the United States Patent Office.

Before the Board of Appeals.

SIMONDS

vs.

WHEELER.

Patent Interference No. 60,839 between the application of Dewey T. Simonds. Filed May 17, 1928. Serial No. 278,588 and the application of Harold A. Wheeler. Filed July 7, 1927. Serial No. 203,879. Signaling Systems.

Mr. Charles E. Tullar for Simonds.
Messrs. Pennie, Davis, Marvin & Edmonds for Wheeler.

This is an appeal by the party Wheeler from the decision of the Examiner of Interferences dissolving the interference on the ground that the counts are unpatentable over the prior art and denying appellant's motion to amend on the ground that the proposed counts are also unpatentable over the art. Subsequently to the decision of the Examiner of Interferences a patent has issued which the party Simonds urges is an anticipation of all of the counts and proposed counts and his request that this patent be considered by us has been granted. After the introduction of the new patent appellant withdrew his appeal as to 373 certain counts and proposed counts and presented three other proposed counts for consideration. Count 5 which reads as follows may be regarded as representative.

5. In a high-frequency receiving system, an electron discharge device having an anode circuit, a cathode and a grid, a tuned circuit connected between said cathode and grid

whereby said receiving system may be adjusted to respond to current of desired frequency, sound reproducing means, means for supplying current from said device to said sound reproducing means, means for controlling the static potential on said grid in response to the intensity of the received current thereby to produce a substantially constant volume of sound from said sound reproducing means over a range of intensities of received current, and means responsive to the magnitude of current flowing in said anode circuit for visually indicating the condition of adjustment of the tuned circuit with reference to the frequency of received current whereby said tuned circuit may be adjusted in accordance with said last named means independently of the audible indication supplied by the sound reproducing means.

The subject matter involved relates to radio receivers provided with an automatic volume control and with a visual indicator to show when the set is tuned to true resonance with the incoming carrier current. It is unnecessary to describe the particular details of the structures disclosed by the parties or in the references as the question before us is substantially one of whether the addition of a visual indicator shown in one patent involves invention when added to the structure of another patent where it would serve the same purpose.

The patent to Friis discloses a volume control of the type called for by the appealed claims. The patent to Perry discloses a visual indicator employed in connection with the head phones of a receiving set to aid in the tuning.

374 There has been some argument advanced that the difficulty with the volume control set of Friis would not be obvious but in our opinion those skilled in this art were well aware of the fact that receivers function better when set to true resonance and we consider it was apparent that with the volume control it is not possible to determine when that point is reached merely by listening to the output as the sound is substantially constant from the time that the field of the station has been entered sufficiently to create the desired volume until this portion of the field is passed. It appears that the variations in currents can be readily measured by a visual indicator where they cannot be distinguished by ear. It is our opinion, there-

should be given to the various claims when considered in connection with Heising but since we regard the combination of Perry and Friis as affording adequate reason for considering the subject matter of the claims unpatentable we do not deem it necessary or advisable to definitely rule upon the pertinency of Heising to the claims before us, particularly as this patent has never been considered by the examiner. If this question is raised *ex parte* the principal examiner may consider this patent without prejudice.

The appeal is dismissed as to all of the counts and proposed counts that have been withdrawn by appellant. The decision of the Examiner of Interferences is affirmed as to the remaining appealed claims for the reason above
378 stated. It is held that the subject matter of the newly-presented claims 63, 64 and 65 does not involve invention over the prior art as disclosed by the patents to Friis and Perry relied upon in rejecting the other claims under consideration.

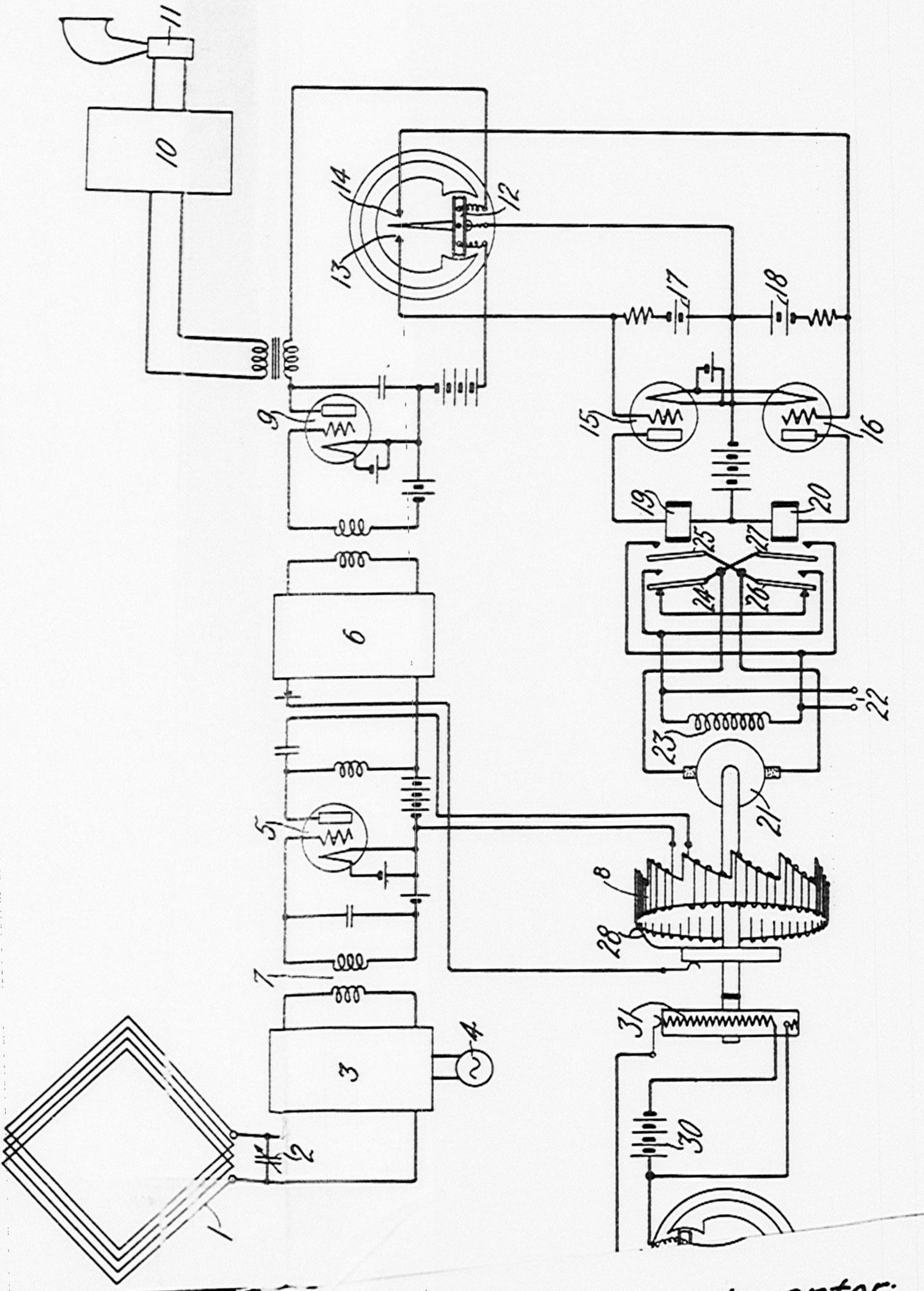
F. M. HOPKINS,
Assistant Commissioner,
W. L. THURBER,
Examiner-in-Chief,
E. T. MORGAN,
Examiner-in-Chief,
Board of Appeals.

February 26, 1932.

Sept. 15, 1931. R. A. HEISING 1,823,360

SIGNALING SYSTEM

Filed July 6, 1925



Inventor:
Raymond A. Heising
by J.G.Roberts Att'y.

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Patented Sept. 15, 1931 **1,823,360**

UNITED STATES PATENT OFFICE

RAYMOND A. HEISING, OF MILLBURN, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

SIGNALING SYSTEM

Application filed July 6, 1925. Serial No. 41,708.

This invention relates to signaling systems and more particularly to a method and means for measuring the strength of a received signal.

Due to the relatively low intensity of the signals received at a radio receiving station, it is impractical to directly connect a graphic recorder in the receiving circuit in order to obtain a record of the intensity of the received signal. An ordinary graphic recorder requires a current many times greater than that produced by received signals of maximum intensity even though several stages of amplification are employed. Since the amplitude of a detected signal varies as the square of the amplitude of the received wave, a recorder constructed in the usual manner would be operative over only a small range, as the upper values would be off the scale or the lower values would be unreadable, according to the scale selected. Furthermore, the quality of a received signal is frequently poor due to increases or decreases in the strength of the wave, commonly called fading caused by variations in the transmission medium.

It is an object of this invention to measure and record the strength of a received signal. Another object is to produce a continuous graphic record of the variation in amplitude of a received signal. A further object is to maintain constant the strength of the received signal energy in a radio receiver. A feature of the invention is to provide a system in which available indicating or recording instruments may be used to indicate variations in signal strength over ranges of 100 to 1 or more with approximately equal accuracy. Another feature is to provide a system in which a signal may [illegible] dicated in convenient units, such as transmission units.

These objects and others which will be apparent as the nature of the invention is disclosed, are accomplished by employing in connection with a radio receiving apparatus including a detector and amplifying means, means for varying the amount of amplification or gain as the strength of the received signal varies.

In the particular system, to be hereinafter described, the gain obtained in the amplifier is controlled by means of a potentiometer adapted to vary the ratio of the current in two successive stages of amplification. A graphic recorder is connected in such a manner that it records the position to which the above mentioned potentiometer is adjusted. By making a continuous record of the adjustments of the potentiometer which are required to maintain constant the signal in the output circuit of the amplifier, the strength of the original signal may be ascertained.

The novel features which are believed to be characteristic of this invention will be pointed out with particularity in the claims appended hereto. However, the invention itself, its objects and advantages, the manner of its organization and the mode of its operation will be better understood by referring to the following description taken in connection with the accompanying drawing forming a part thereof, in which the single figure illustrates a diagrammatic representation of one type of signaling system embodying this invention.

The incoming signal waves may be received over a transmission line or by means of a radio antenna. For the purpose of completely and clearly disclosing a practical arrangement embodying the invention, it will be hereinafter described as applied to a radio receiving system.

The figure shows a loop aerial 1, tuned by condenser 2, adapted to impress the incoming wave upon a radio receiving system herein shown as including a detector 3, a source of beating oscillations 4 and amplifying devices 5 and 6. Local oscillations supplied [illegible] the incoming signals to produce a wave of desired intermediate frequency which is impressed upon amplifier 5 through transformer 7 tuned to the intermediate frequency. Obviously, a tuned circuit or wave filter, selective of the intermediate frequency, could be used in place of the resonant transformer 7.

Amplifier 5 is coupled to amplifier 6, which may include any number of stages, by means of potentiometer 8 adapted to vary the ratio of the output potential of amplifier 5 to the potential applied to the input circuit of amplifier 6. Signal energy of intermediate frequency which has been amplified to the desired intensity in the above mentioned amplifiers is rectified in the device 9, and used to operate suitable indicating means. Thus the rectified current may be impressed upon a device 10 capable of amplifying low frequency signals and used to actuate suitable signal responsive means 11, herein shown as a loud speaker.

The direct current component of rectified current in the output circuit of detector 9 varies with the intensity of the signaling impulses and is supplied to a three-position relay 12, the movable contact of which is adapted to engage the contacts 13 and 14, respectively, as the amplitudes of the direct current impulses are greater or less than a predetermined value. Space discharge devices 15 and 16 have their grids polarized by sources 17 and 18, respectively, so that substantially no space current flows through them. Relays 19 and 20 are adapted to be energized by the space current flowing through these tubes. Relay 12 operates to short-circuit source 17 or 18 as its movable contact engages the contact 13 or 14, respectively.

Relays 19 and 20 are so connected that in the position shown, corresponding to that in which the three-position relay is in a neutral position, the armature of motor 21 is disconnected from the line 22 and is short-circuited. Field 23 of this motor is permanently connected across line 22.

When relay 12 operates to engage contact 13, the grid polarizing source 17 of vacuum tube 15 is short-circuited and the potential of the grid becomes sufficiently positive to enable current to pass through its anode circuit through the relay 19 to actuate armatures 24 and 25 and connect the armature of motor 21 across line 22.

When contact 14 is engaged by the movable contact of relay 12, relay 20 operates in a similar manner to actuate armatures 26 and 27 by means of which the armature of motor 21 is connected across line 22 in a manner such that current flows through the motor armature in a direction opposite to which it flows when the relay 19 is energized.

of motor 21, makes contact with potentiometer 8 in such manner that the ratio of the voltage across the potentiometer to the voltage applied to amplifier 6 is determined by the position of the motor armature.

Potentiometer 8 is preferably wound in such a manner that the resistance between the movable contact and one end of the winding is an exponential function of the angular position of the movable member. This may be accomplished in one way by constructing the potentiometer in sections as shown, each section being so designed that the resistance is an exponential function of the number of turns. In order to avoid abnormally large or abnormally small turns as the ends of the winding are approached, the sections are made of substantially the same size and are wound with approximately the same size wire, and a resistance which has a value sufficient to produce the desired resistance for the section as a whole is connected in parallel to each section.

By winding the potentiometer exponentially, the accuracy of setting or stopping of the motor by the relays will be the same at all values of field strengths. Other windings may be used if desired for other effects or relations.

Graphic recorder 29 is connected across battery 30 by means of potentiometer 31 which is mounted to rotate with the armature of motor 21. Variations in the resistance of the potentiometer 31 as the motor rotates will control the application of varying potentials to recorder 29 from battery 30 which will actuate the recorder to produce a graphic record of the amount of rotation of the potentiometer arm 28.

In the normal operation of this system the current in the plate circuit of the detector 9 will be such that the armature of relay 12 is kept in the position shown; however, when the strength of the received signal impressed upon detector 9 varies from a predetermined value, contact 13 or 14 will be closed. Relay 19 or 20 will be actuated to control the rotation of motor 21 until such an adjustment of potentiometer 8 is effected that the gain of amplifiers 5 and 6 is adjusted to restore to its original predetermined intensity the energy supplied to the rectifier 9. When this occurs, relay 12 assumes a neutral position, relays 19 and 20 assume the position shown, and the armature of motor 21 is disconnected from the line and is short-circuited, to give a braking effect which will immediately cause the motor to come to rest. Since the movable arms of potentiometer 8 and potentiometer 31 are mechanically connected to the same shaft operated by motor 21, the rotation of the motor will produce equal angular movements of the two arms. The amount of rotation necessary to compensate for any variation in field [illegible] will determine the potential applied to recorder 29 by potentiometer 31 and will be recorded by the recorder. The strength of the incoming signal may be determined by noting the amount of rotation necessary to vary the gain in the receiving set by an amount such that the amplitude of the detected current remains constant.

As the operation of the motor and potentiometer 8 is practically instantaneous with variations in signal intensity, the strength of the signal current supplied to device 11 will be maintained constant irrespective of variations of the received signal.

By including amplifier 5 between detector 3 and potentiometer 8, the incoming high frequency wave is more effectually suppressed, due to the selective action of transformer 7. Moreover the intensity of the potential applied to the amplifier 6 is raised to such a value that it may be more readily and accurately controlled by the potentiometer.

Any desired relation may be obtained between the strength of the received wave and the record made by the recorder 29, by varying the relation between the resistance of potentiometer 31 and the angular movement of its movable element. In the case of a potentiometer wherein the resistance is directly proportional to its angular position, the indication obtained by the recorder will be a logarithmic function of the strength of the received wave. Such a recorder will then indicate variations of field strength in transmission units.

Although this invention has been shown as applied to a particular system, however, it is not to be limited thereto, but only in accordance with the scope of the invention as defined by the following claims.

What is claimed is:

1. In a signaling system, means for receiving a signal, means for subjecting said signal to a variable amount of amplification, means for varying said amplification in response to the strength of the received signal to produce an amplified signal having substantially constant amplitude, and means for indicating the logarithm of the amplitude of the original received signal.

2. In a system of the class described, means for receiving a signal, means for amplifying said signal, a potentiometer for controlling the amount of amplification to which said signal is subjected, means for controlling the position of said potentiometer comprising a relay actuated by said received signal, whereby said potentiometer is adjusted in such a manner that the strength of the amplified signal remains substantially constant, and means operable under the influence of said potentiometer to record a graph whose departure from normal is a logarithmic function of the departure from normal of the strength of received signals.

3. A signal receiving system comprising a detector and [illegible] means for impressing the incoming signal and local oscillations upon said detector to produce an intermediate frequency wave, a selective circuit for selecting and a space discharge amplifier for amplifying said intermediate frequency wave, a potentiometer for varying the intermediate frequency energy applied to said amplifier, means for rectifying said intermediate frequency signal, a relay actuated by said rectified current adapted to control said potentiometer in such a manner that the strength of said rectified current remains substantially constant, and a graphic indicating means for recording the adjustment of said potentiometer.

4. In a signal receiving system, means for receiving a transmitted wave, a source of local oscillations, means for combining said wave with oscillations from said source to produce a wave of intermediate frequency, means for amplifying said intermediate frequency wave, a logarithmic potentiometer for controlling the amount of said amplification, means for rectifying said intermediate frequency wave, a signal responsive device actuated by the rectified current, a three-position relay actuated by said rectified current, a plurality of space discharge devices, means controlled by said relay for governing the impedance of said devices, a motor operatively associated with said potentiometer, relays actuated by said discharge devices whereby the rotation of said motor is controlled by said three-position relay, means whereby in one position of said three-position relay the armature of said motor is short circuited, a second potentiometer associated with said first mentioned potentiometer, a graphic recorder controlled by said second mentioned potentiometer, whereby the adjustment of said first mentioned potentiometer is indicated, said system being adapted to impress upon said signal responsive device a current of substantially constant amplitude.

5. In a signaling system, means for receiving and detecting a transmitted signal, means for indicating the strength of the signal received comprising a graphic recorder, and devices controlled by said detector whereby the record made by said recorder varies in accordance with the powers to which a given number must be raised to represent the absolute value of received energy.

6. A receiving system comprising an amplifier for received energy, means for varying the amplifying power of said amplifier, means for maintaining the amplified energy supplied by said amplifier constant within narrow limits, said means for maintaining including a displaceable element, means whereby unit displacements of said element correspond to changes in amplification pro- [illegible] and an element for linearly recording displacements of said displaceable element.

7. A receiving system comprising an amplifier for received energy, means operable under the influence of variations in received energy for varying the amplifying power of said amplifier, means for maintaining the amplified energy supplied by said amplifier constant within narrow limits, said means for maintaining including a displace-

able element, and means whereby unit displacements of said element correspond to changes in amplification proportional to powers of a number.

In witness whereof. I hereunto subscribe my name this 29th day of June A. D., 1925.

RAYMOND A. HEISING.

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March 2, 1926. 1,574,780

H. A. AFFEL

MEANS FOR AND METHOD OF MODULATION

Filed Oct. 5, 1921 3 Sheets-Sheet 1

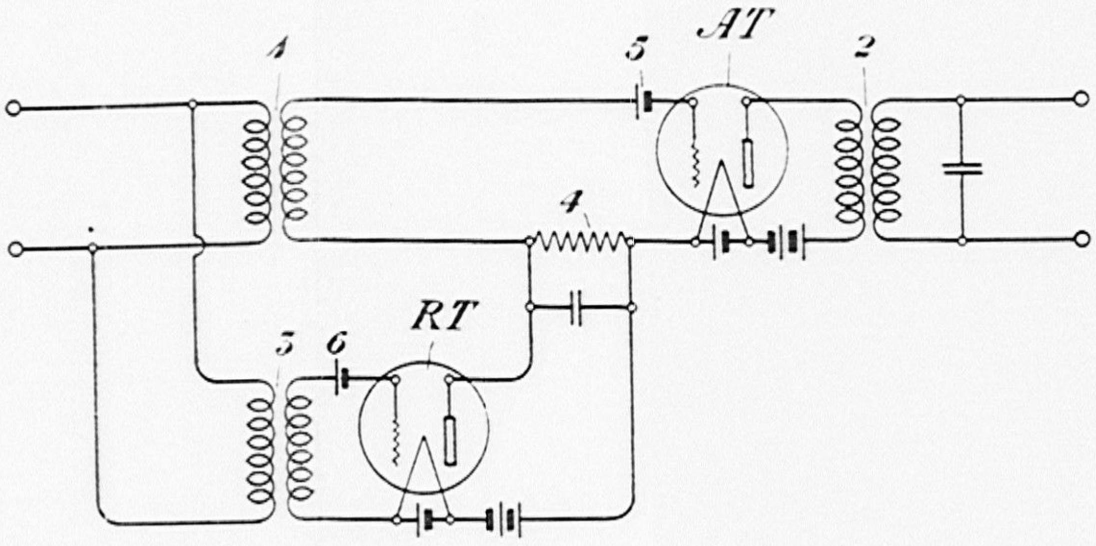
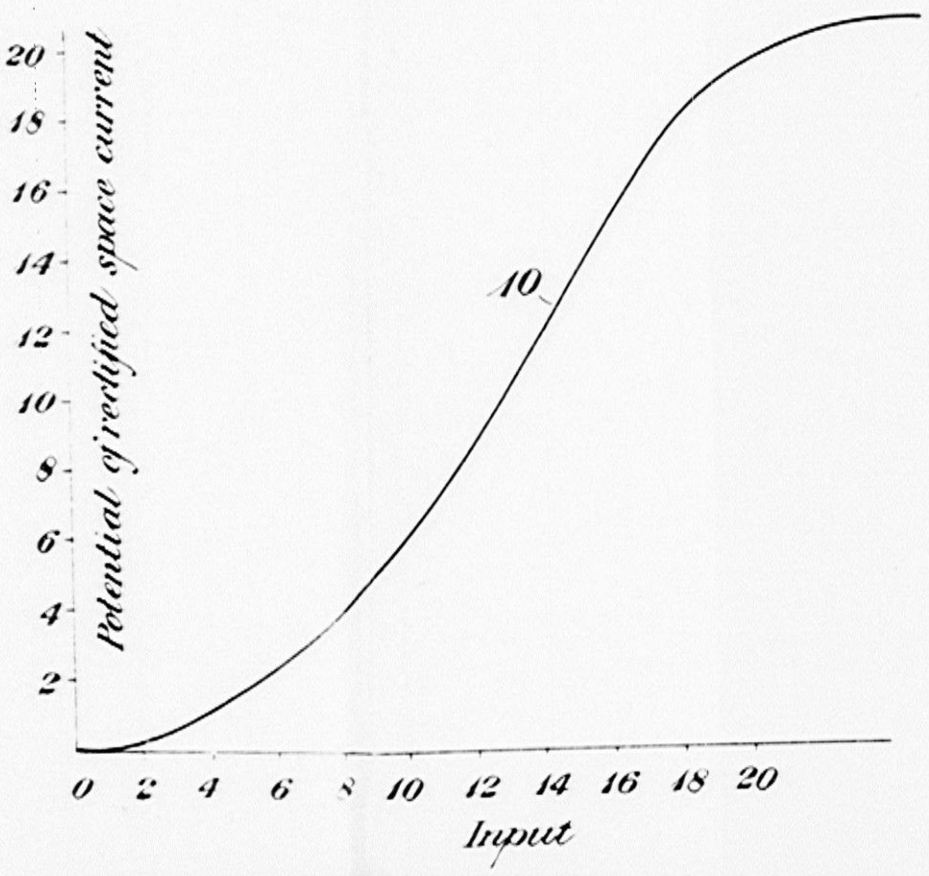


Fig. 1



Inventor
H. A. Affel

By his Attorney
G E Folk

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March 2, 1926. H. A. AFFEL 1,574,780

MEANS FOR AND METHOD OF MODULATION

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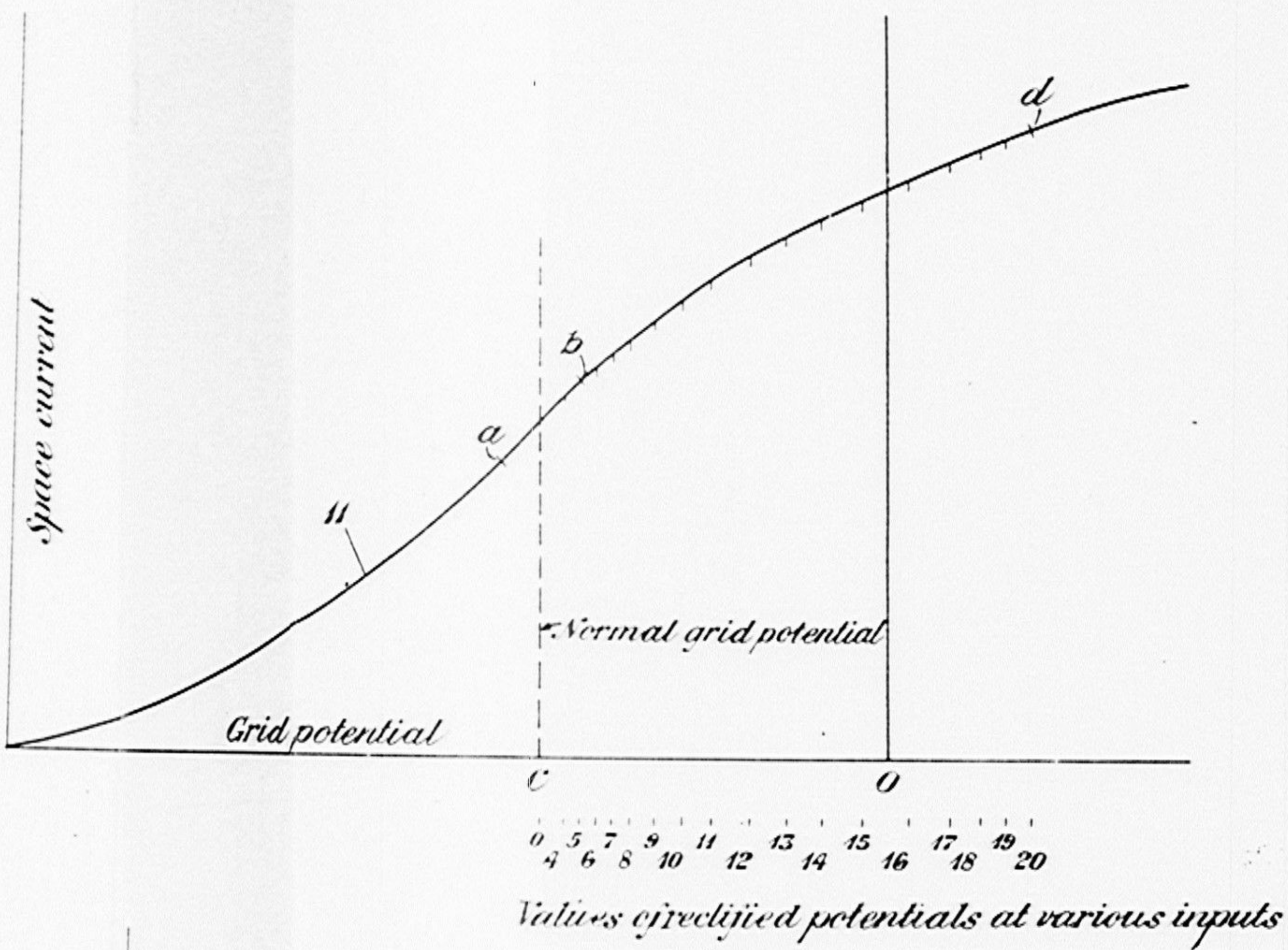

Fig. 3

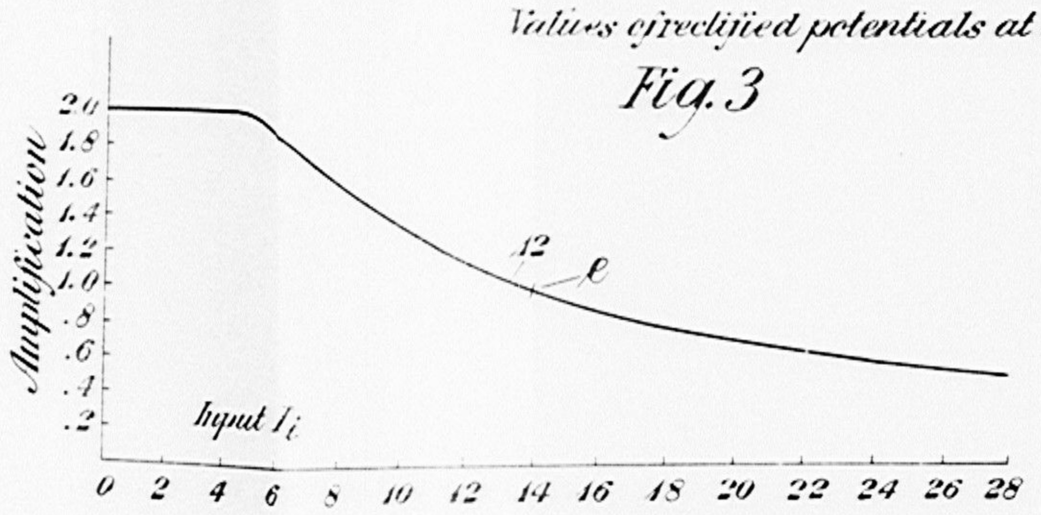

Fig. 4

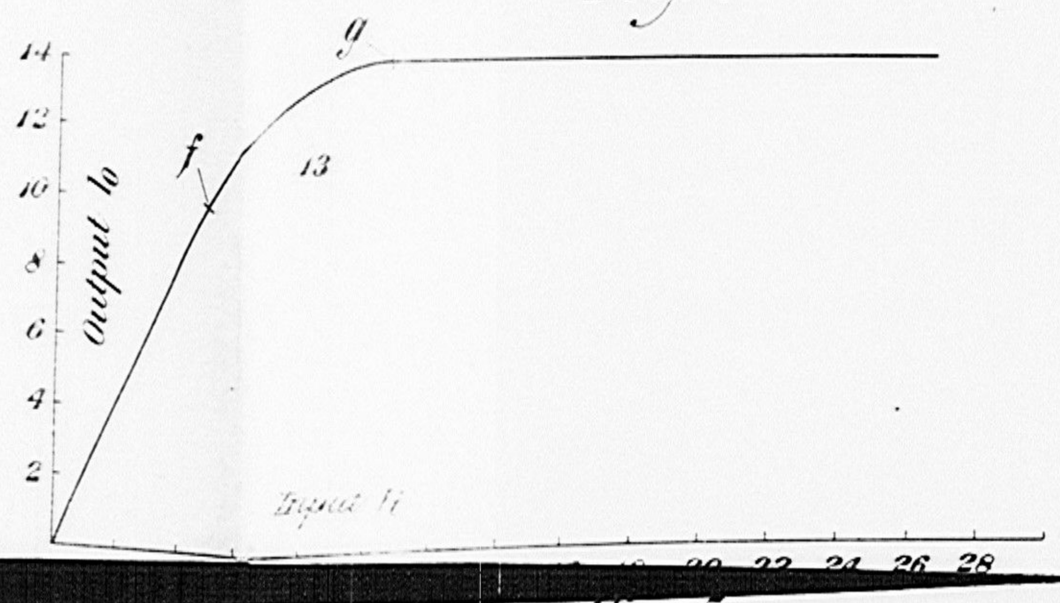

Fig. 5

Inventor
H.A. Affel
By his Attorney
GEFolk

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162

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H. A. AFFEL

MEANS FOR AND METHOD OF MODULATION

Filed Oct. 5, 1921 3 Sheets-Sheet 3

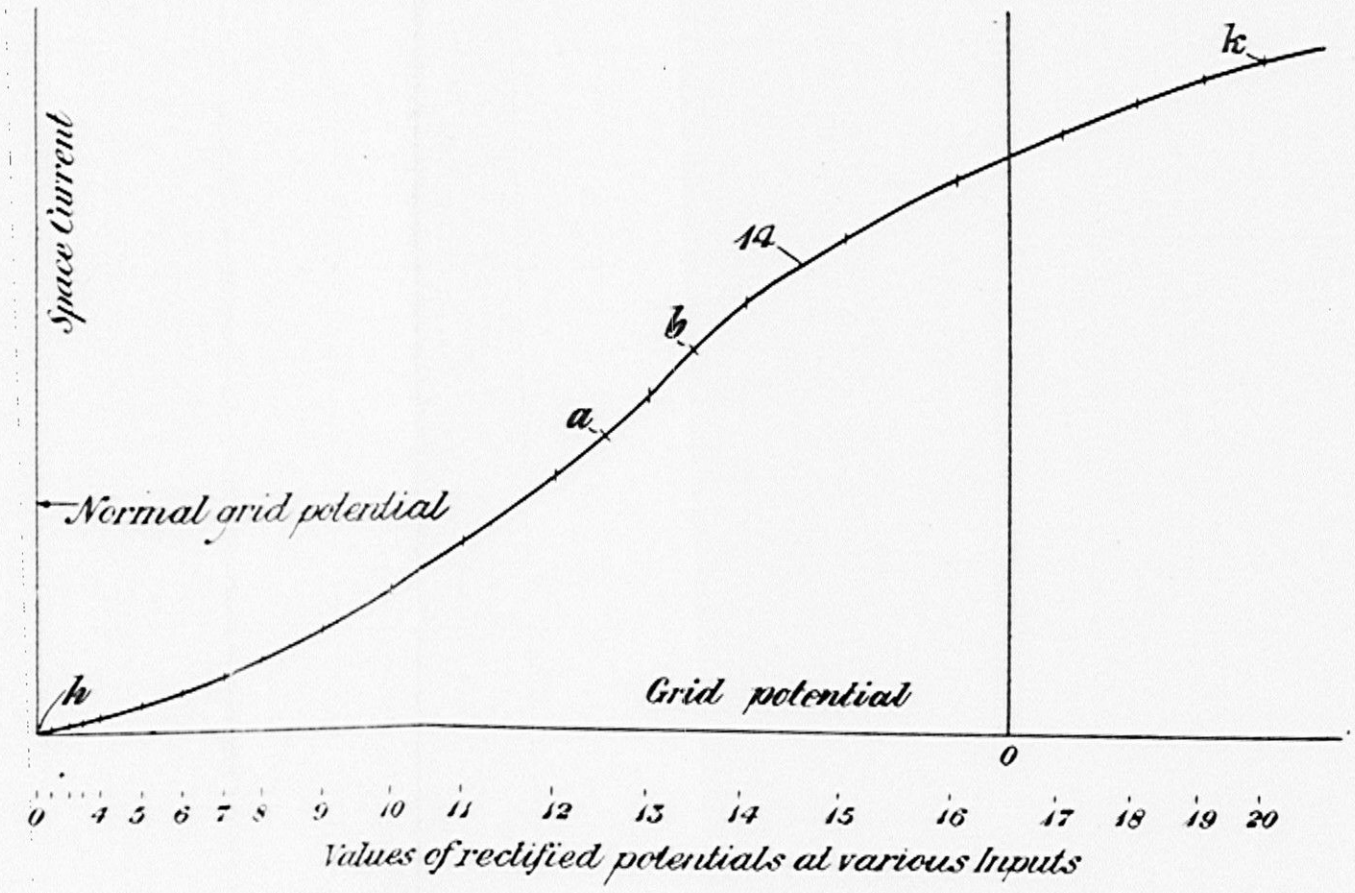

Fig 6

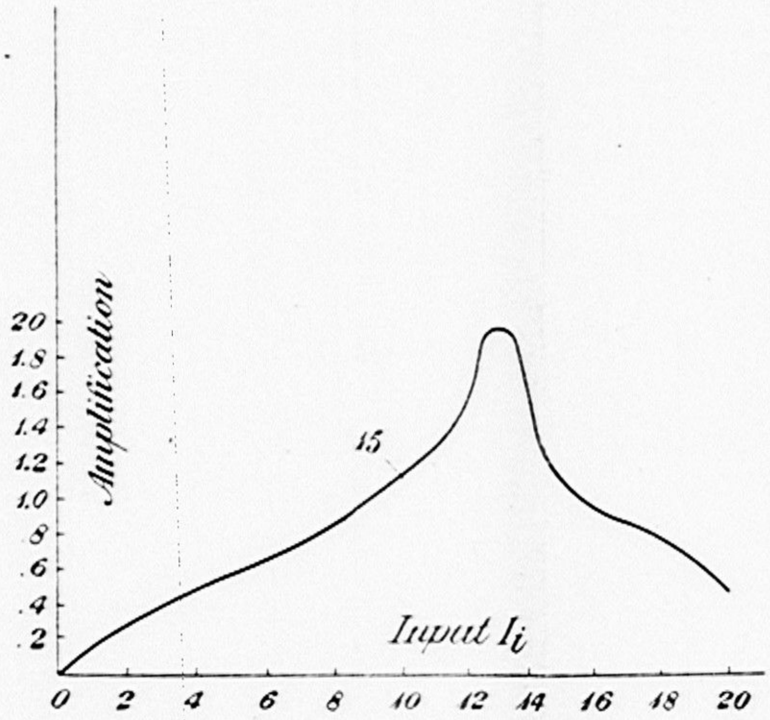

Fig. 7

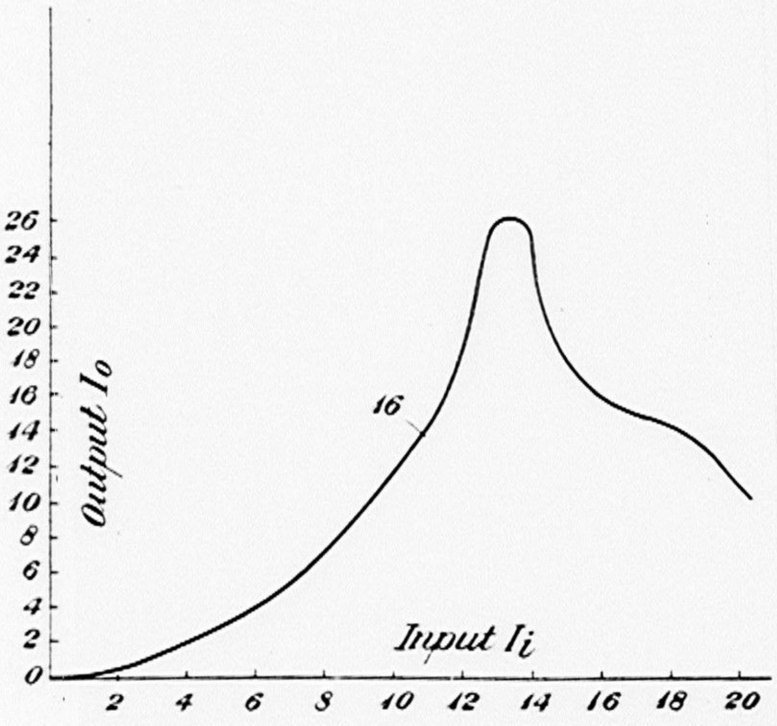

Fig. 8

Inventor
H. A. Affel

By his Attorney G E Folk

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UNITED STATES PATENT OFFICE.

HERMAN A. AFFEL, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR AND METHOD OF MODULATION.

Application filed October 5, 1921. Serial No. 505,530.

To all whom it may concern:

Be it known that I, Herman A. Affel, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Means for and Methods of Modulation, of which the following is a specification.

This invention relates to translating devices and more particularly to means for variably controlling the amplitude of the output current from a transmission circuit with reference to the amplitude of the input current applied by the circuit.

One of the objects of the invention is to produce an amplifying or translating device whose amplification may be made to vary for different amplitudes of input current. Another object of the invention is to control the amplification of an amplifying device directly by the amplitude of the input current supplied by the device. Another object of the invention is to provide a translating device which will discriminate between input currents of different amplitudes. Another object of the invention is to provide a vacuum tube amplifier whose static grid potential will be a function of the amplitude of the input currents. It is further intended that any of these actions may be carried on with substantially no distortion of the wave form of the incoming current.

These objects, as well as other objects of the invention more fully appearing hereinafter, are accomplished by applying to a rectifier or distorting arrangement a portion of the input energy to be transmitted through a translating system, and using the rectified energy for determining the static grid potential of a vacuum tube amplifier. By suitable adjustments of the characteristics of the amplifier and the rectifying or distorting arrangement any desired relation within reasonable [illegible] between the amplitudes of the input and output currents of the system.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, Figure 1 of which is a circuit diagram of an arrangement embodying the principles of the invention, and Figs. 2 to 8 inclusive of which are curves illustrating the operation of the arrangement disclosed in Fig. 1.

Referring to Fig. 1, AT designates a vacuum tube amplifier to the grid circuit of which input energy may be applied through a transformer 1, and from which output energy may be drawn through a transformer 2. The amplification of the tube AT may be varied by variably adjusting the static grid potential of the tube. In order to adjust the static potential of the grid and hence the amplification of the tube in accordance with the amplitude of the input current, a rectifying tube RT is provided. The rectifying tube RT is so arranged that a portion of the input energy applied by the transformer 1 may be applied to the grid circuit of the rectifying tube through a transformer 3. The output circuit of the rectifying tube RT is connected across the terminals of a resistance 4 in the grid circuit of the amplifier AT, so that the rectified potential will determine the potential of the grid of the amplifier AT. As the rectified potential will be a function of the amplitude of the input energy applied to the amplifier AT, the amplification of the amplifier AT may thus be made to depend upon the amplitude of the input energy. The usual C battery 5 may be applied to the grid circuit of the amplifying tube AT to determine its normal grid potential and a similar battery 6 may be applied to the grid circuit of the rectifier RT to determine the normal potential of the grid of the rectifier.

By suitably adjusting the elements of the tubes RT and AT to obtain desired characteristics, and by suitably adjusting the proportions of energy applied directly to the amplifying tube and directly to the rectifying tube, it is thought possible to obtain, within reasonable limits, any desired relation between the amplitude of the input current and the amplitude of the output current [illegible] justments, different operating requirements may be met.

For example, the translating arrangement above described may be used to equalize the current output of the system for input amplitudes above some critical value. This would permit of stabilizing the operation of some relay or other translating device independent of substantial input current variations.

In order to understand quantitatively how

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such a result may be obtained, attention is called to the curves of Figs. 2 to 5 inclusive. In Fig. 2 the curve 10 shows the variation of the potential of the rectified space current of the tube RT for different amplitudes of input current. This curve, it will be noted, is similar in form to the usual characteristic curve of a three-element vacuum tube as plotted between grid potential and space current; in fact, the curve 10 may be considered as a reproducton of the characteristic curve of the tube since the input energy is a direct function of the grid potential, and the potential of the rectified space current is directly proportional to the plate current of the tube.

In Fig. 3, 11 may be taken as the characteristic curve of the amplifying tube AT, the curve being plotted between grid potential and space or plate current, as is the common practice. This curve may be given various forms by suitable adjustments of the constants of the tube as is well known, and in the instance given, the characteristic curve 11 is substantially a straight line between the points *a* and *b*. Over this portion of the curve the amplification will be constant. Above the point *b* the curve gradually flattens out so that the slope of the curve is decreased. The same is true of the portion of the curve below the point *a*. As the amplification of the tube depends upon the slope of the characteristic curve over the range in which the tube is operating, it will be apparent that the amplification gradually decreases above the point *b* until the slope is decreased to such a point that, depending of course on the absolute values of the constants involved, an actual loss in transmission may possibly occur, instead of a gain. The same thing may hold true for the portion of the curve below the point *a*.

Let us assume that with the grid of the amplifying tube AT at neutral or zero potential a space current would flow as indicated at *o*. The potential of the grid battery 5 may be then so fixed that the tube will normally operate at the point *c*, which is here taken as the midpoint of the straight line portion of the characteristic. Let us further assume that the amplitude of the input energy, as applied to the grid of the amplifying tube AT, is sufficiently small so that at any given point the variation in amplitude will be [illegible] row portion of the characteristic. This will insure a minimum distortion of the input wave form. Let us assume that the rectified output potential of the rectifying tube RT will be of sufficient amplitude in the case of the greatest amount of input energy to be considered so that when said rectified potential is applied to the grid circuit of the amplifier, it will shift the operating point of the curve from the point *c* to a point well along the upper portion of the curve, as for example, the point *d*. In general these assumptions would probably mean that tube AT would be of larger physical dimensions that tube RT.

In the case assumed, the rectified potential will be applied in such a direction as to oppose the potential of the grid battery 5, so that as the amplitude of the input energy is increased the normal grid potential will become less and less negative, thus shifting the operating point further upward over the curve. The values of the controlling potentials for the amplifying tube for different values of input current may be obtained from the curve 10 of Fig. 2. These values are indicated by the points laid out immediately below the horizontal axis of the curve, the points being designated by the numbers indicating the corresponding input amplitudes.. In other words, the points indicate values of rectified potential but the numbers applied to the points refer to corresponding input amplitudes.

The amplification of the tube at any given input amplitude may be obtained by determining the slope of the curve 11 at a point immediately above the number designating a given input potential in Fig. 3. Curve 12 of Fig. 4 is a plot of the amplification of the tube for different amplitudes of input current, as determined from the curve 11 of Fig. 3. For example, if the input current applied to the amplifier is zero, the static grid potential of the amplifying tube will be the normal grid potential indicated at *c* in Fig. 3. At this point the slope of the curve is forty-five degrees, which is arbitrarily assumed, for purposes of illustration, to correspond to an amplification of two times. As the amplitude of the input current is increased up to five units, the slope remains the same and hence the amplification as plotted in Fig. 4 is the same, consequently the curve 12 is horizontal out to this point. As the amplitude is increased the slope of the curve decreases for amplitude beyond five units, so that the amplification correspondingly decreases. For example, for an input current of 14 units, in Fig. 3, the slope of the curve is such that the amplification is unity. As the slope decreases beyond this point with corresponding decrease in amplification, the functioning of the tube represents an actual loss in transmission. Thus, in the curve 12 of Fig. 4, the portion of the curve to the right of the point *e* represents a loss in transmission, and that portion of the curve to the left of the point *e* represents a gain.

In order to obtain a clear picture of the relation between the input amplitude and the output amplitude for the system, it is necessary to translate the values of amplification in Fig. 4 into values of output cur-

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tween *a* and *b* in Fig. 6. The amplification then decreases for further increase in the input current, this being due to the falling off of the slope of the curve 14 in Fig. 6.

The output current values may be obtained by multiplying the input current by the amplification, as described in connection with Fig. 5. By plotting input currents along the horizontal axis and output currents along the vertical axis, the curve 16 of Fig. 8 is obtained. An inspection of this curve shows that as the input current is increased up to a value in the neighborhood of 13 units, the output current increases, the increase being very rapid in the neighborhood of 13 units, which point corresponds to the maximum output current. For further increase in the amplitude of the input current, the output current falls off very rapidly. It follows at once from an inspection of the curve in Fig. 8, a system such as that described may be made highly discriminatory with regard to the amplitude of the input current.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method of varying the amplification of a vacuum tube amplifier which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in adjusting the static grid potential in accordance with the amplitude of the current so produced.

2. The method of controlling the amplification of a vacuum tube amplifier which consists in rectifying a portion of the input energy and applying the direct current component of the rectified energy to the grid circuit of the tube to determine the static potential thereof.

3. The method of controlling the amplification of a vacuum tube amplifier which consists in rectifying a portion of the input energy and applying the direct current component of the rectified energy to the grid circuit of said amplifier to adjust the amplification in accordance with the static potential applied by the grid.

4. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static grid potential of the vacuum tube in accordance with the amplitude of the current so produced that a predetermined relation between the input energy applied to the system and the ouput energy from the system will be obtained.

5. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static potential of the grid of the tube in accordance with the amplitude of the current so produced that the output energy will be a maximum for a predetermined amplitude of the input energy.

6. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static potential of the grid of the tube in accordance with the amplitude of the current so produced that the system will discriminate against input energies having amplitudes less than a predetermined maximum.

7. The method of operating a translating circuit, including a three-element vacuum tube, which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in so controlling the static potential of the grid of the tube in accordance with the amplitude of the current so produced that the system will discriminate against input energies having amplitudes greater than a predetermined amplitude.

8. The method of operating a translating circuit, including a three-element vacuum tube, which consists in so controlling the static potential of the grid of the tube in accordance with the amplitude of the input energy that the system will transmit the greatest output energy for a predetermined input energy and the output energy will be less for input amplitudes either greater or less than the predetermined amplitude.

9. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the tube, and so controlling the static potential of the tube by means of the direct current component of the rectified energy that a predetermined ratio between the input energy applied to the system and the output energy transmitted from the system will be obtained.

10. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the

rent. Since the amplification is merely the ratio of the output current I_0 to the input current I_1 the value of the output current may be obtained for each value of input current by multiplying the input current by the amplification as obtained from the curve 12. The curve 13 of Fig. 5 is obtained by plotting input currents against the output currents thus obtained. An inspection of the curve 13 shows that up to the point *f*, corresponding to an input current of five units, the output current increases by a constant ratio so that the curve is a straight line to this point. As the amplification falls off beyond this point the slope of the curve changes and beyond the point *g*, corresponding to about eleven units of input current, the curve remains horizontal, in other words, for input currents greater than eleven units, the output current of the system will be constant.

This equalization of the amplitude of the output current for any input amplitude above a given limiting value may be obtained by suitable adjustment of the constants of the two tubes involved, and is not dependent upon the particular values above described, these values merely being assigned arbitrarily in order to obtain a quantitative understanding of the principles underlying this aspect of the invention. Other adjustments may be used to give different results, for example, by suitable adjustments, the apparatus may be made to function as a marginal discriminating device in which the greatest action of a relay or other piece of detecting apparatus in the output circuit obtains when the input current is of a particular value and values of input current greater or less than this particular value will be discriminated against. Such a device might be used, for example, in the reduction of interference in carrier or radio transmission systems. In such a case the normal signal would be received at the amplitude for which a maximum output current will obtain. If an interfering current of greater or less value than a signaling current is impressed upon the system, the output current will be considerably decreased, so that the marginal responsive device will be unaffected.

In order to obtain a quantitative idea of how the tube should be adjusted in order to secure this result, attention is called to the curves of Figs. 6, 7 and 8. In Fig. 6 the curve 14 is the characteristic curve of the amplifier AT plotted in the usual manner between grid potential and plate current. For purposes of illustration this curve is made identical with the curve 11 of Fig. 3, the amplification being uniform between points *a* and *b* and decreasing when the operation of the tube is at points beyond *a* and *b*.

It will be remembered that in order to obtain the equalization of the output current as above described, the apparatus of Fig. 1 was adjusted so that the amplifying tube operated from a point *c* intermediate between the points *a* and *b* to a point on the curve, as indicated at in Fig. 3. In the present instance it is proposed to operate along the curve from the point *h* to the point *k*. The grid battery 5 is therefore adjusted so that the normal grid potential will be negative, a sufficient number of volts to prevent any space current from flowing. While it is not necessary that the normal grid potential should be such as to prevent any space current from flowing, the grid should be normally sufficiently negative so that the tube would be operating on the lower part of its characteristic where the amplification is low.

The rectified controlling potential applied to the grid circuit from the tube RT must, in the case of the maximum input energy to be considered, be sufficient to shift the operating point of the curve to a point of low amplification on the upper part of the curve beyond the point *b*. Accordingly the constants of the tube RT will be adjusted to increase its amplification or the component of the output potential to be applied to the amplifying tube will be increased so that the range of rectified potentials corresponding to various inputs will extend from, say, the point *h* to the point *k* in Fig. 6. The various rectified potentials corresponding to the current input values will be obtained as before from the curve 10 of Fig. 2, and the points below the horizontal axis in Fig. 6 represent potentials corresponding to different input amplitudes.

As in the case of Fig. 3, the amplification for any given grid potential will depend upon the slope of the curve at that point. The rectified potentials applied to the grid circuit of the amplifying tube AT tend to neutralize the normally negative potential of the grid more and more as the amplitude of the input current increases. The amplification of the tube for a given input current may be obtained by determining the slope of the curve 14 at a point immediately above the number representing the desired input in the row of numbers below the horizontal axis of Fig. 6. By plotting the values of the amplification for different values of the input current in a manner similar to that described in connection with Fig. 4. the curve 15 of Fig. 7 will be obtained. From this curve it will be seen that the amplification for an input current of zero value will be zero and the amplification gradually increases to a maximum for an input current of 13 units, this input current corresponding to the intermediate point of the straight portion of the characteristic curve lying be-

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from the original bound volume

tube, and so controlling the static potential of the tube by means of the rectified energy that the system will discriminate against input energies having amplitudes less than a predetermined maximum.

11. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the tube, and so controlling the static potential of the tube by means of the direct current component of the rectified energy that the system will discriminate against input energies having amplitudes greater than a predetermined amplitude.

12. The method of operating a translating circuit, including a three-element vacuum tube, which consists in applying input energy to the tube, rectifying a portion of the input energy before it is applied to the tube, and so controlling the static potential of the tube by means of the rectified energy that the system will transmit the greatest output energy for a predetermined input energy and the output energy will be less for input amplitudes either greater or less than the predetermined amplitude.

13. The method of operating a vacuum tube amplifier which consists in producing a current whose amplitude is proportional to the envelope of the alternating input energy applied to the tube and in shifting the operating point of the tube along its characteristic axis in accordance with the amplitude of the current so produced.

14. The method of operating a vacuum tube amplifier which consists in applying thereto energy variations whose maximum amplitude will be relatively small as compared with the total range of the tube, and shifting the operating point of the tube along its characteristic curve to a point determined by the amplitude of the envelope of the alternating energy variations applied thereto.

15. The method of operating a vacuum tube amplifier which consists in applying energy variations to said amplifier having an amplitude relatively small as compared with the range of the tube, rectifying a portion of the energy and applying the direct current component of the rectified potential to the grid circuit of the tube to shift the working point of the tube along its characteristic curve in accordance with the amplitude of the energy variations.

16. In a translating system, a three-element vacuum tube, means to apply energy variations to said tube, means to produce a current whose amplitude is proportional to the envelope of the alternating energy so applied, and means to adjust the working point of said tube along its characteristic axis in accordance with the amplitude of the current so produced.

17. In a translating system, a three-element vacuum tube, means to apply energy variations to said tube, means to rectify a portion of the energy of said variations, means to apply the direct current component of the rectified potential to said vacuum tube to shift its working point along its characteristic curve in accordance with the amplitude of the energy applied by the tube.

18. In a translating system, a three-element vacuum tube, means to apply alternating currents to the grid circuit of said tube, means controlled by said alternating current for producing a direct current potential whose value is determined by the amplitude of said alternating current, and means to apply said direct current potential to said vacuum tube to control its operating point.

19. In a translating system, a vacuum tube amplifier, means to apply alternating current to the input circuit of said amplifier, a vacuum tube rectifier, means to apply said alternating current to said vacuum tube rectifier, thereby producing rectified direct current, and means to control the static potential of the grid of said vacuum tube amplifier in accordance with the amplitude of said rectified direct current.

In testimony whereof, I have signed my name to this specification this 21st day of September 1921.

HERMAN A. AFFEL.

Defendant's Exhibit J.

[Third Edition.]

PATENT SPECIFICATION

Application Date: July 14, 1925. No. 18,000/25.

259,664

Complete Accepted: Oct. 14, 1926.

COMPLETE SPECIFICATION.

Improved Gain Regulator of Thermionic Amplifiers.

(Communicated by Bell Telephone Laboratories, Incorporated, a corporation of the State of New York, having a principal place of business at 463, West Street, New York, State of New York, United States of America.)

We, Western Electric Company Limited, of Connaught House, Aldwych, London, W.C. 2, England, a British company, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the regulation of the gain of thermionic wave amplifying systems and more particularly to methods of and means for controlling & maintaining at uniform level the intensity of received signals in a carrier wave receiving system by regulation of the gain of a thermionic amplifier.

One object of the invention is to improve the constancy of the over-all transmission equivalent in radio communication systems.

It is well known that radio signalling waves are subject to extremely variable attenuation and that the strength of the received signals may vary so greatly as to make it difficult and even impossible at times to obtain satisfactory communication. These variations may be due to the regular changes between day and night conditions or they may be the much more rapid changes which are commonly known as "fading" effects. Slow changes of the former kind may be compensated by manual adjustment of the sensitivity of the receiving system, but compensation of the much more rapid fading effects required some form of automatic adjustment.

To maintain a uniform transmission equivalent in a radio system it is necessary that any change in the attenuation of the medium be immediately offset by an opposite change in the gain characteristic of the receiving system. Methods of securing this result have been proposed and consist in radiating along with the signal wave a "pilot" wave of constant amplitude, and employing at the receiving station currents corresponding to this wave to control the sensitivity of the receiving system. The control apparatus, which includes mechanical elements, is so arranged that if the received pilot wave diminishes in intensity the sensitivity of the receiving system is increased by a corresponding amount and vice versa.

The pilot wave, being free from signal variations, is modified only by the attenuation of the transmission medium and therefore the control of the receiver gain is responsive only to changes in the attenuation of the medium. In most communication systems the signal is transmitted as a modulated carrier wave, which may be considered as a wave of single frequency and varying amplitude or alternatively as a group of waves including a constant wave of the carrier frequency and side waves representing the signal. It is therefore unnecessary to provide a special pilot wave as the carrier wave, when separated from the side waves, is satisfactory for the purpose.

By the present invention an improved means is provided for controlling the sensitivity of the receiving system in accordance with the intensity of the received signal. The control is effected without the intervention of any mechanical device & without the use of a pilot wave, and may be made to respond accurately to and to compensate changes in the transmitting medium having periods of less than one fiftieth of a second.

In the detailed description which follows the invention will be described as applied to radio telephony for the reason that the need is greatest in that field. It is to be understood, however, that it

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may be applied equally well to any type of signal wave system regardless of the nature of the medium of transmission.

Fig. 1 of the accompanying drawings shows a receiving system in which the invention is embodied;

Fig. 2 shows a special characteristic curve for an amplifier which is adapted to illustrate the operation of the invention; and

Fig. 3 is the operating characteristic curve of the receiving system of Fig. 1.

The receiving system of Fig. 1 is of the double detection or super-heterodyne type in which an intermediate frequency carrier wave is produced by demodulation of the incoming wave with an auxiliary wave locally generated. The incoming waves are received by the loop antenna 1 which may be tuned to resonance by means of condenser 10. The auxiliary wave is supplied from a local source 2 and is impressed upon the high frequency circuit through a small loop 11 which is coupled to the receiving loop 1. Two stages of high frequency amplification are provided by the tandem connected space discharge amplifiers 3 and 4, both the incoming waves and the auxiliary waves being amplified thereby. The first stage of detection occurs in the space discharge demodulator 5 from the output of which the demodulation products are delivered through a transformer 12 to the band-pass filter 6.

The function of filter 6 is to separate out and transmit only the intermediate frequency waves corresponding to the difference between the incoming wave frequencies and the auxiliary wave frequency. It is preferable that the intermediate frequency waves should occupy a band centered in the neighbourhood of 50,000 cycles per second, the width of the band being made sufficient to include the intermediate frequency carrier and all side frequencies necessary for the proper reproduction of the signal. The filter may be of the well known Campbell type.

The selected intermediate frequency band is amplified in the amplifier-detector 7, in which the final step of detection to produce the low frequency signal currents also takes place. The low frequency currents are delivered to an amplifier 8 and the amplified current is supplied to the signal reproducer 9, which is illustrated as a loud speaking telephone.

The amplifier-detector 7 and the amplifier 8 are indicated only in conventional form, the particular type and arrangement used being unimportant, since any well known devices adapted to perform the desired functions may be used.

The local auxiliary wave source 2 may be any type of oscillation generator but should be adjustable so that the frequency of the intermediate carrier wave and the associated side frequencies may be within the range selected by the filter 6.

The control current by which the sensitivity of the receiver is regulated is selected from the output of the amplifier-detector 7 by the resonant circuit 13, 14, connected in shunt to its output circuit which is tuned to the frequency of the intermediate carrier wave. Its voltage after being amplified in the space discharge amplifier 15 is impressed upon the space discharge detector 16 in the output of which it produces a steady direct current. The control electrode 26 of the detector is so polarised by the battery 27 that little or no space current flows normally; consequently in accordance with the well known characteristics of space discharge detectors, an alternating e.m.f. impressed upon the control electrode produces a direct current in the space path which increases as the impressed e.m.f. increases.

Space current to all tubes except tube 16 is shown as being supplied from a common source 31.

The output circuit of the detector 16 includes the space discharge path between the anode 29 and the cathode 25, a separate space current source 17 and a fixed resistance 18. The cathode and one terminal of the resistance 18 are connected together at ground potential. Choke coil 19 and condenser 20 serve to prevent the flow in resistance 18 of any alternating current corresponding to the impressed intermediate frequency wave.

For reasons that will be explained later, the high frequency amplifiers 3 and 4 are provided with balancing capacities 21 to neutralise the coupling between the output and the input circuits of the amplifiers due to the internal electrode capacities.

In the first high frequency amplifier, the cathode is connected through a relatively large capacity 22 to the mid-point of the receiving loop, the potentials of the end terminals of which are therefore balanced with respect to the cathode and are of opposite sign. One terminal of the loop is connected to the input or control electrode 23 of the amplifier and the other is connected through the balancing condenser 21 to the anode 24. The capacity of the condenser 21 is substantially equal to the direct capacity between the electrodes 23 and 24. By this means, any current that might be transmitted directly from the input to the output of the amplifier through the electrode capacity is neutralised by an equal and opposite current transmitted through the balancing condenser.

The circuit of the second stage is similar and operates in a similar manner. The system of neutralisation described is well-known.

The control of the sensitivity of the system is secured by causing the rectified output current of the detector 16 to modify the control electrode potentials of the amplifiers 3 and 4. The cathodes of these amplifiers are connected to ground, and the control electrodes are connected to the ungrounded terminal of resistance 18, whereby they are caused to assume the potential of this point. This potential is determined by the current flowing in the resistance.

As current can flow only in the direction from ground to the anode of the detector 16, the fall of potential across the resistance 18 is such as to impress a negative potential upon the amplifier control electrodes. An increase of the current in the resistances 18 will increase the negative potential applied to the control electrodes of the amplifier and in consequence will reduce the amplifier space currents. This is equivalent to increasing the internal resistance of the amplifier and is effectual in reducing their over-all amplification. It follows then that an increase in the intensity of the incoming wave, by producing an intermediate frequency carrier wave of larger amplitude, causes an increased current to flow in the resistance 18, and thereby reduces the sensitivity of the receiving system.

The relationship between the space path impedances of the amplifiers 3 and 4 and the polarising potentials of their control electrodes is shown qualitatively by the curve in Fig. 2. The ordinates are proportional to the space path impedance R_0; the abscissæ are proportional to the steady current I_c flowing in the resistance 18, and therefore to the polarising potentials applied to the control electrodes of the amplifier. The vertical dotted line $J\ J^1$ corresponds to the potential that is just sufficient to reduce the space current to zero, the space path impedance becoming infinite under this condition.

The detected current I_c cannot exceed the value corresponding to the abscissa OJ; since it requires for its production that some part of the incoming wave be repeated by the amplifiers and this cannot take place if the amplifiers are blocked. A continually increasing intensity of the incoming wave may cause the detected current to approach indefinitely close to the limiting value, but it can never attain such a value that the amplification of waves by the amplifier is actually stopped. The detected current will therefore be substantially constant for all intensities of the incoming wave greater than some low value depending on the initial sensitivity of the system. Since the detected current remains constant, it follows that the intermediate frequency carrier wave from which it is produced must also remain constant.

The relationship between the current intensity of the intermediate frequency carrier wave and the e.m.f. of the incoming signal carrier wave is shown by the curve of Fig. 3. The abscissæ are proportional to the e.m.f. (Ef_1) of the incoming carrier wave measured at the input terminals of the amplifier 3, and the ordinates are proportional to the current intensity, denoted by I_d, of the intermediate frequency carrier wave at the point where it enters the band filter 6. The intensity of signals received at 9 will, of course, be proportional to I_d.

The horizontal line K, K^1 represents the limiting value that the current I_d may approach, but which it cannot equal or exceed. The ordinate OK is proportional to the intensity that produces the limiting value OJ in Fig. 2, of the control current I_c. The slope of the curve at the origin of the co-ordinates is proportional to the initial sensitivity of the system; namely the sensitivity that would be obtained if the control system were made inoperative, or the sensitivity that is obtained for such low intensities of the incoming wave that the effect of the control is negligible. Obviously, as the initial sensitivity of the system is increased, the control system will be operative to effect regulation at lower and lower intensities of the incoming waves.

The uniformity of the intermediate frequency carrier wave resulting from this method of control, corresponds to transmission through a medium of constant attenuation; the sound waves of the impressed message are reproduced with a strength that faithfully follows their original intensity regardless of the variations to which radio waves are subject in the medium.

It should be noted that the control affects only those waves that are repeated by the controlled amplifiers in the normal manner; it is not effective upon such portion of the waves that may be transmitted directly through the capacities of the amplifier electrodes.

Strong incoming waves might, under certain conditions, cause sufficient current to be transmitted through the amplifier capacities to cause the control current I_c to reach and exceed the limiting value at which the amplifiers become blocked. Stronger wave intensities would then be uncontrolled, the amplifiers operating merely as fixed capacity networks to produce a fixed attenuation of the waves. By neutralising the coupling between the input and the output circuits of the controlled amplifiers in the manner hereinbefore described, the direct transmission of the incoming wave is largely prevented and the range of intensities that can be controlled is greatly increased.

The use of two controlled amplifiers in tandem further increases the range that can be controlled by increasing the attenuation to which directly transmitted waves are subjected. Satisfactory control may, however, be obtained over a wide range of intensities using only one controlled amplifier.

An additional feature of the system described above that tends to increase the operating range of intensities, is the arrangement whereby the auxiliary wave from the local source is subjected to the action of the controlled amplifiers. As the intensity of the incoming wave increases and, through the action of the control circuit, reduces the effective amplification of the amplifiers, the strength of the auxiliary wave e.m.f. impressed upon the detector 5 is reduced. Hence the intermediate frequency carrier approaches the limiting value at a slower rate than it would if the auxiliary wave were not controlled, and further, the component of the intermediate carrier due to the incoming wave is very small. Both of these factors are effective in extending the operating range.

With this arrangement, the demodulation of strong incoming waves in the detector 5 takes place with a considerably weakened auxiliary wave. Such a condition may give rise to a larger number of harmonics and other undesired modulation products, but these are suppressed by the band filter 6.

An alternative arrangement of the circuit may be used in which the auxiliary wave is impressed directly upon the demodulator 5 and is therefore not subject to the action of the controlled amplifiers. To permit the use of this arrangement, a switch 28 is provided by which the local source 2 may be connected to a coupling transformer 30, the secondary of which is connected in series with the input circuit of the demodulator. With this arrangement, constant conditions in the demodulator are obtained since the incoming wave is maintained at substantially constant intensity by the control current.

The response of the control to changes in the strength of the incoming wave is exceedingly rapid; that it is not instantaneous is due only to the presence of the condensers 22 and 20 which are connected in parallel with the resistance 18. The condensers 22 are inserted to provide a low impedance connection for the high frequency waves between the cathodes and the tuning coils in the amplifier input circuits. The condenser 20 is provided to absorb the alternating current in the output of the detector 16. They are effective in reducing the rapidity of response because they require a certain small time to charge or discharge when the applied potential is changed. It is found that the total capacity may be as great as 1 m.f.d. without increasing the response time above one fiftieth of a second.

In experimental tests with a system of the type described but having only one controlled amplifier, received signals have been maintained constant in strength within 10% while the impressed wave intensities varied from a minimum to a maximum value one thousand times greater.

The operation of the invention has been described in connection with a double detection system, but it is obvious that the principles involved may be applied to the control of receiving systems in which no auxiliary wave is used and which employ only one demodulation of the incoming waves. Instead of an intermediate frequency carrier wave, the carrier component of the incoming waves would be selected to produce the control current, the selection, as in the system described, being made after the wave has passed through the controlled amplifier. The use of the double detection system, however, by establishing an intermediate carrier wave of relatively low frequency, makes it possible to separate the carrier more completely from its accompanying side frequencies and thereby to secure more exact regulation.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. Method of regulating the output of a space discharge amplifier having a cathode, anode and control electrode which comprises rectifying some part of the amplified wave from the said output and impressing a unidirectional potential derived therefrom in the circuit of one

of the said electrodes to control the electronic emission from the cathode to the anode of the said amplifier.

2. Method according to Claim 1, characterised in this, that variations in the said unidirectional potential are caused to vary the cathode, anode impedance of the said amplifier.

3. Method of regulating the amplitude of audible frequency waves translated from modulated and unmodulated carrier waves relayed by a three-electrode space discharge amplifier which comprises rectifying some part of the said carrier waves after amplification and impressing the unidirectional potential derived therefrom on the control electrode of the said amplifier.

4. A carrier wave receiving system adapted to receive and detect signals transmitted by a modulated carrier wave which comprises a space discharge amplifier having a cathode, an anode and a control electrode, an input circuit connected to said cathode and said control electrode upon which the modulated and unmodulated carrier waves may be impressed, means to select from the amplified components an unmodulated component thereof, means to produce a direct current e.m.f. from the said unmodulated component and means to impress said e.m.f. upon said control electrode so that variations in the said e.m.f. will produce corresponding variations in the polarisation of the said control electrode tending to maintain the signal at uniform intensity.

5. A system according to Claim 4, having a source of auxiliary wave, means to demodulate the said modulated carrier wave with waves from said source, means for selecting from the products of said demodulation an unmodulated wave of frequency equal to the difference between the frequencies of signal carrier wave and auxiliary wave, means to produce a direct current e.m.f. from the said unmodulated component, and means to impress said e.m.f. upon said control electrode substantially as and for the purpose described in Claim 4.

6. A system according to Claim 4 or 5, having a plurality of said space discharge amplifiers in tandem, the said input circuit being connected to the first in sequence of the said amplifiers, means to select and rectify an unmodulated component from the amplified waves and means to impress thereby a unidirectional potential simultaneously upon the control electrodes of said amplifiers as and for the purpose described in Claim 4.

7. A system according to Claim 4, 5 or 6, having means for neutralising the grid-anode tube capacity of each amplifier in order to preserve the said amplitude control over an increased range of wave amplitudes impressed in the said input circuit.

8. A system according to Claim 4, 5, 6 or 7, wherein said means for impressing a polarising potential on the grid comprises a resistance element associated with the said input circuit and the said rectifying means supplying the unidirectional potential at the terminals of the said element as and for the purpose described in Claim 4.

9. A system according to Claim 8 having a condenser in shunt to the said element which forms a low impedance path for high frequency waves so that the said polarising potential remains a substantially constant mean of the said rectified carrier wave.

10. A system for maintaining substantially constant the amplified output waves from an amplifier, of which the input waves have a varying amplitude, substantially as described and illustrated.

Dated this 14th day of July, 1925.

WESTERN ELECTRIC COMPANY
LIMITED,
by F. Hutchinson,
Their Attorney.

Abingdon: Printed for His Majesty's Stationery Office, by Burgess & Son.
[Wt. 37A.—125/6/1933.]

259,664 COMPLETE SPECIFICATION

1 SHEET

3rd Edition

[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 1

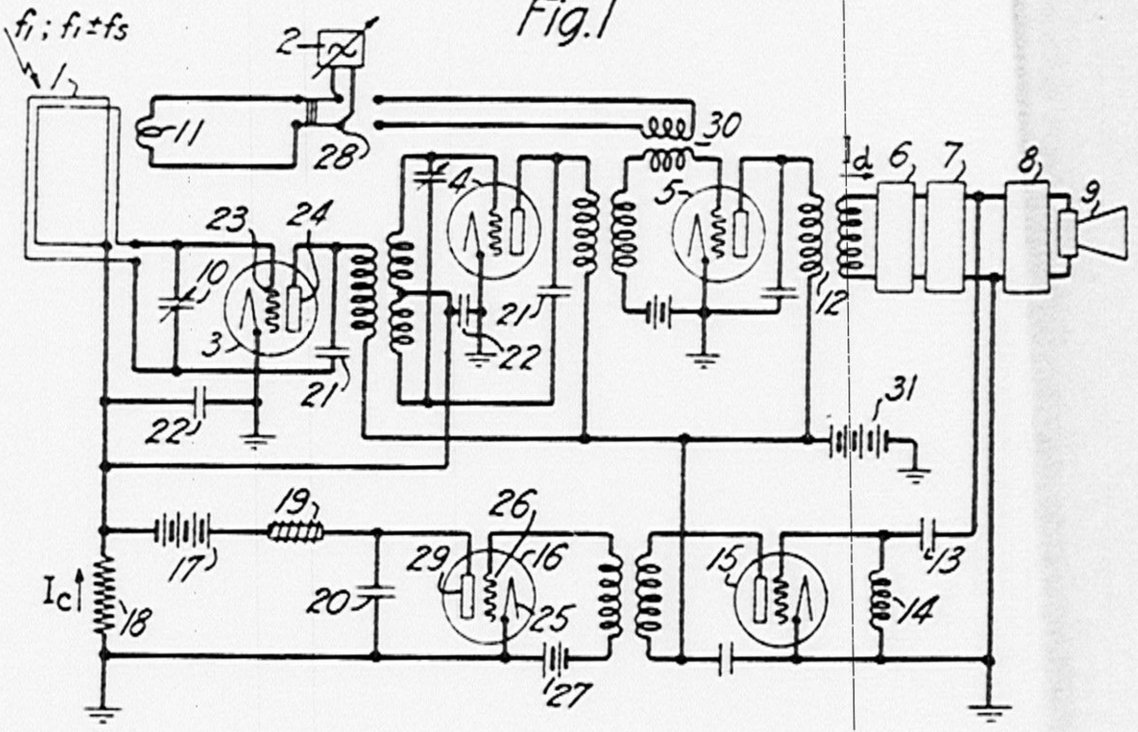


Fig. 2

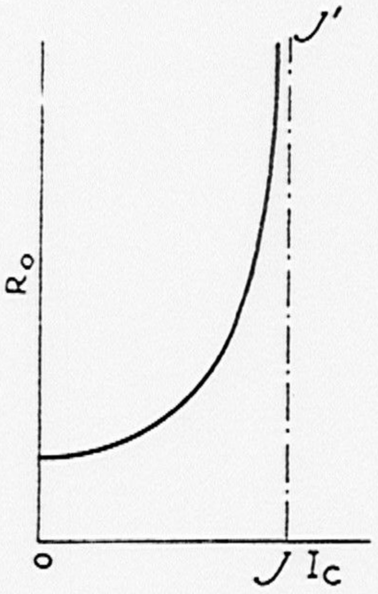
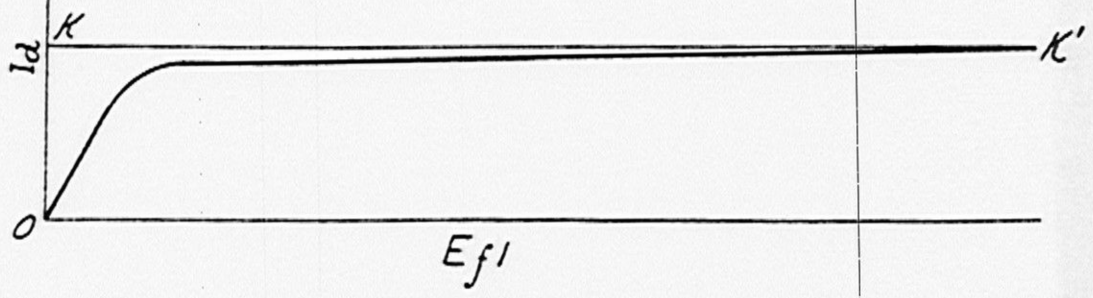


Fig. 3



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In the United States District Court of Appeals for the District of Columbia.

Appeal No. 6576.

Hazeltine Corporation and Harold A. Wheeler, Plaintiffs-Appellants,

vs.

Conway P. Coe, Commissioner of Patents, Defendant-Appellee.

Stipulation.

It is hereby stipulated and agreed by and between attorneys for the respective parties to the above-entitled cause, as follows:

1. That in view of the inclusion in the record of Plaintiffs' Exhibit 4, which is a correct copy of the claims in suit and the specification and drawings of the application of Harold A. Wheeler, Serial No. 203,879, filed July 7, 1927, as of the time the above-entitled cause of action was docketed in the Supreme Court of the District of Columbia, the Clerk of the Court may, to avoid duplication in the printed record, omit therefrom Plaintiffs' Exhibit 3, which is a certified copy of the file wrapper and contents of said application of Harold A. Wheeler, *excepting only* the Examiner's Statement, Paper No. 22 thereof, and the Decision of the Board of Appeals, Paper No. 26 thereof, 401 which two papers of said exhibit are to be included in the printed record.

2. That Plaintiffs' Exhibit 3, aforesaid, is to be filed with the Clerk of the Court as a physical exhibit.

3. That the aforesaid application of Harold A. Wheeler, Serial No. 203,879, was duly filed on July 7, 1927, and that a patent thereon was refused by the Commissioner of Patents, Defendant-Appellee to the above-entitled cause, that no appeal was taken therefrom to the Court of Customs and Patent Appeals, that the Plaintiffs-Appellants filed their Bill in Equity, No. 55,874, in the Supreme Court of

the District of Columbia, as appears from the Transcript of the Record in this case, within six months after such refusal, and that jurisdiction was thereby conferred upon the Supreme Court of the District of Columbia to hear and determine said Bill in Equity in accordance with the provisions of Revised Statutes, Section 4915.

LAURENCE B. DODDS,
Attorney for Plaintiffs-Appellants.

New York, N. Y., October 23, 1935.

R. F. WHITEHEAD,
Attorney for Defendant-Appellee.

Washington, D. C., October 25, 1935.

402 [Endorsed:] 6576. Hazeltine Corp. et al., Appellants, vs. Conway P. Coe, Commissioner of Patents. Designation as to printing exhibits. United States Court of Appeals for the District of Columbia. Filed Oct. 25, 1935. Henry W. Hodges, Clerk.

Endorsed on cover: District of Columbia Supreme Court. No. 6576. Hazeltine Corporation and Harold A. Wheeler, Appellants, vs. Conway P. Coe, Commissioner of Patents. United States Court of Appeals for the District of Columbia. Filed Oct. 22, 1935. Henry W. Hodges, Clerk.